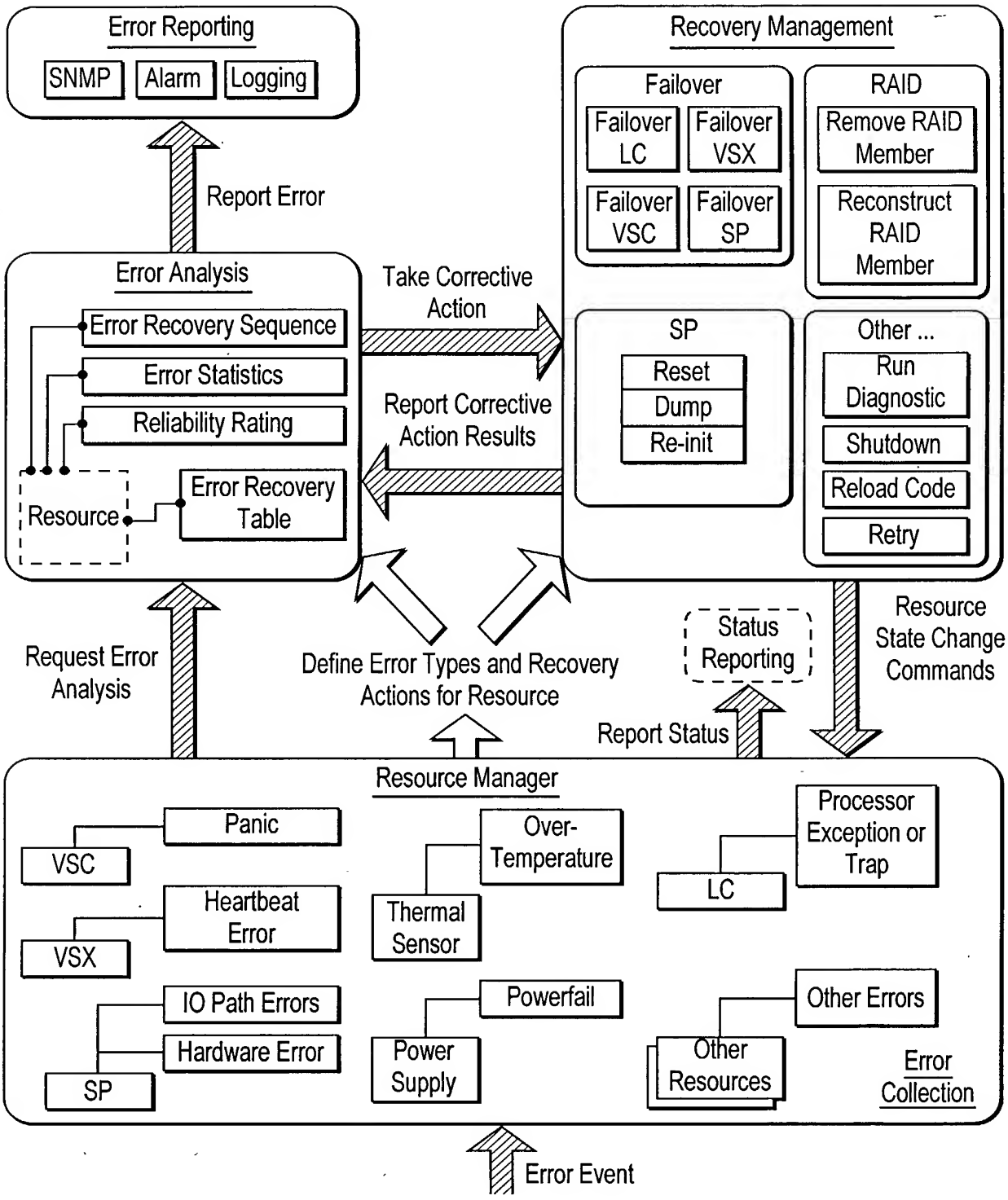


FIG. 1 Error Recovery Architecture

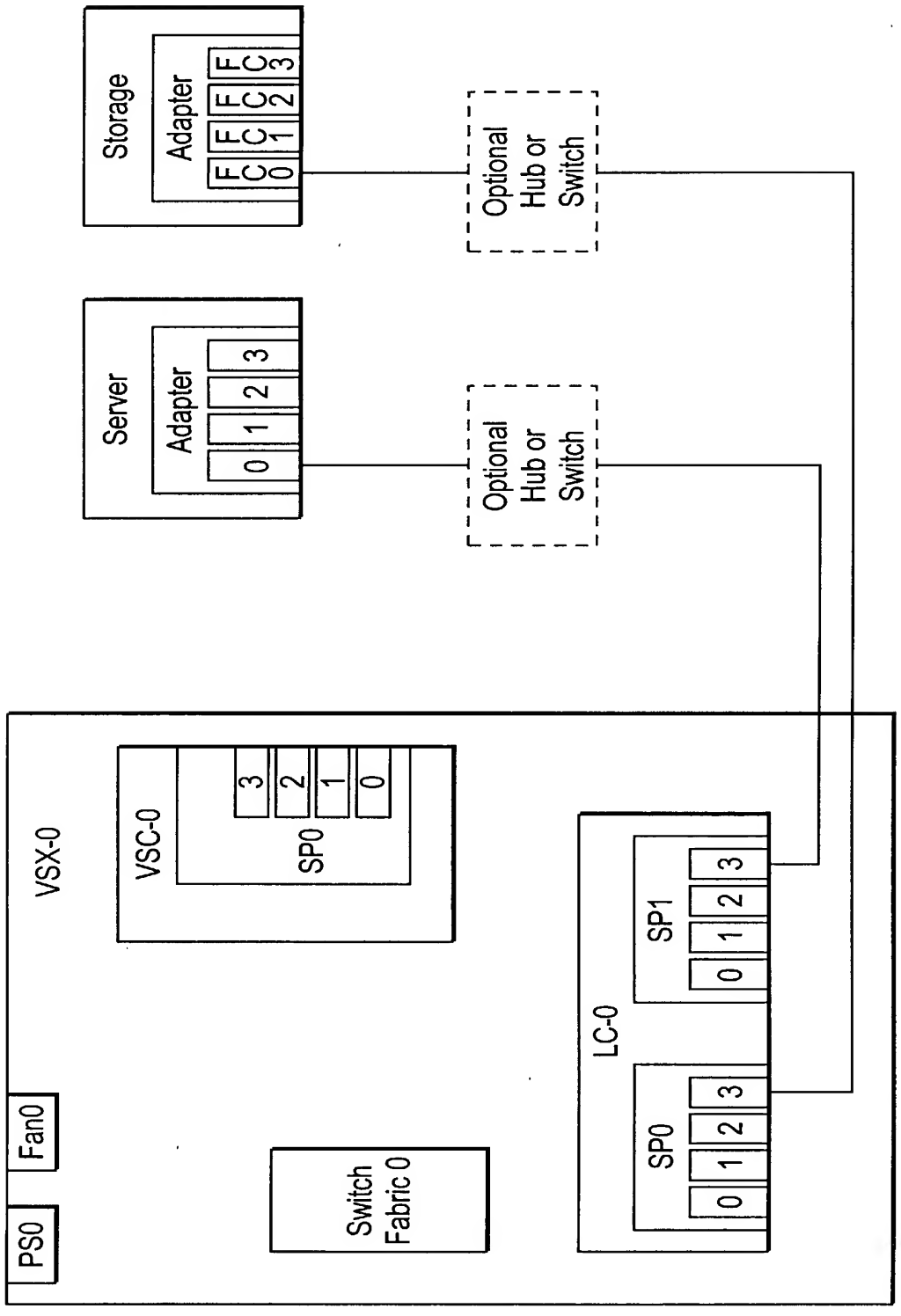


FIG. 2 Non-Fault Tolerant Configuration

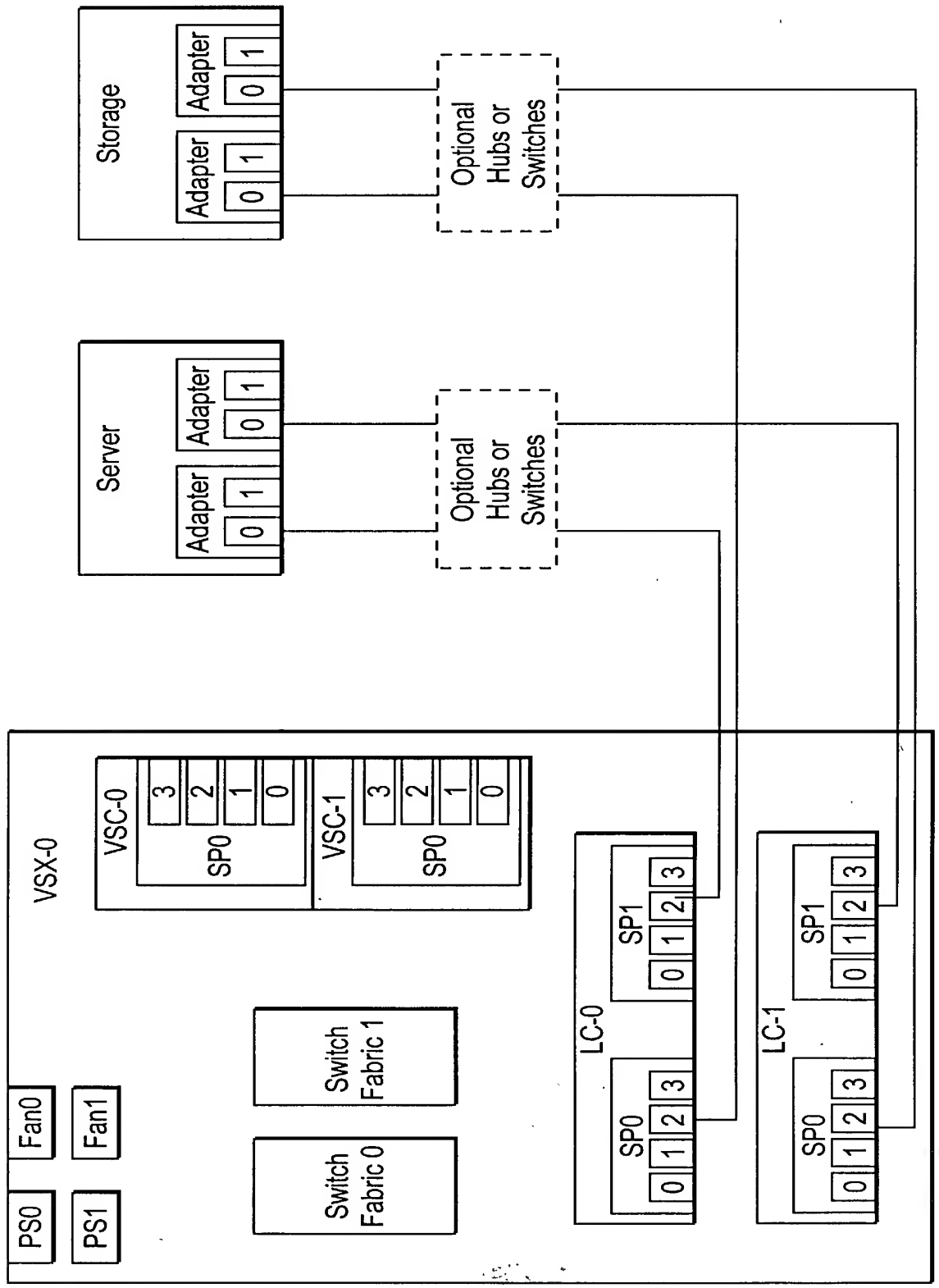


FIG. 3 Fault Tolerant Configuration

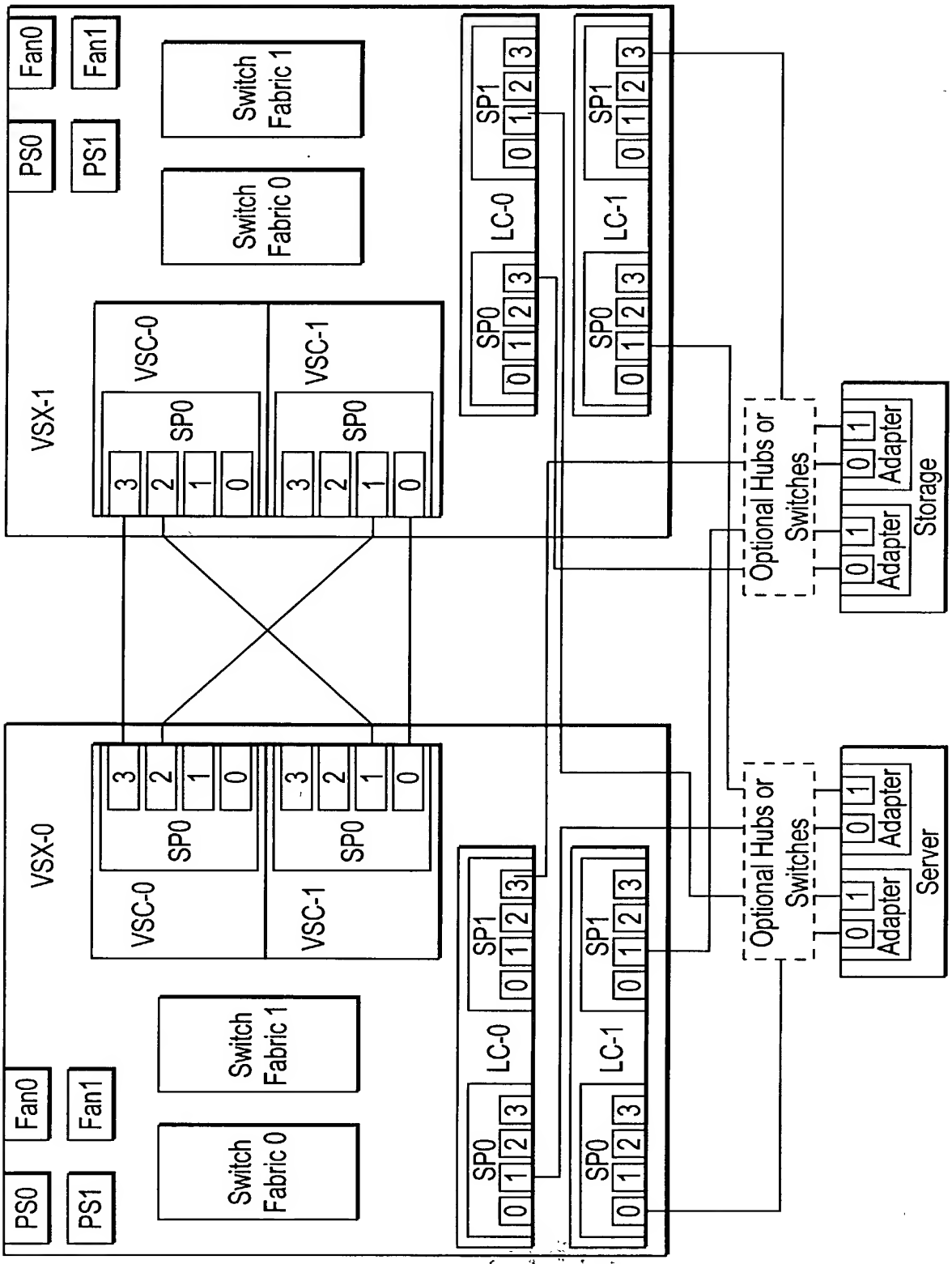


FIG. 4 High Availability Configuration

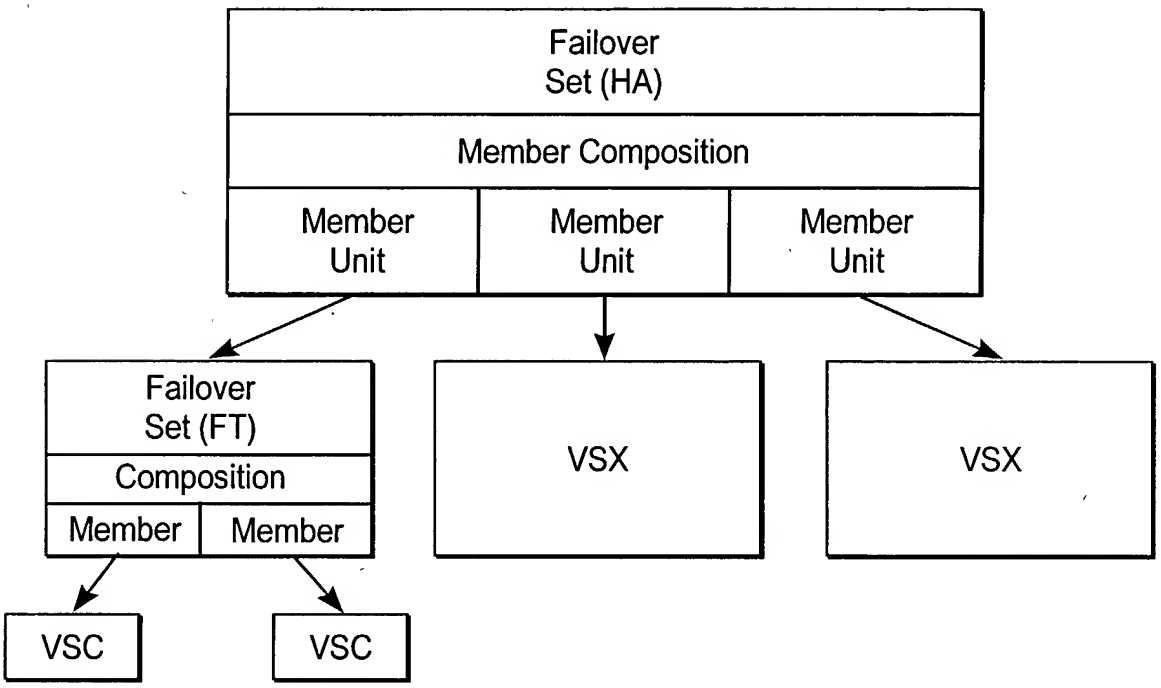


FIG. 5 Components of a Failover Set

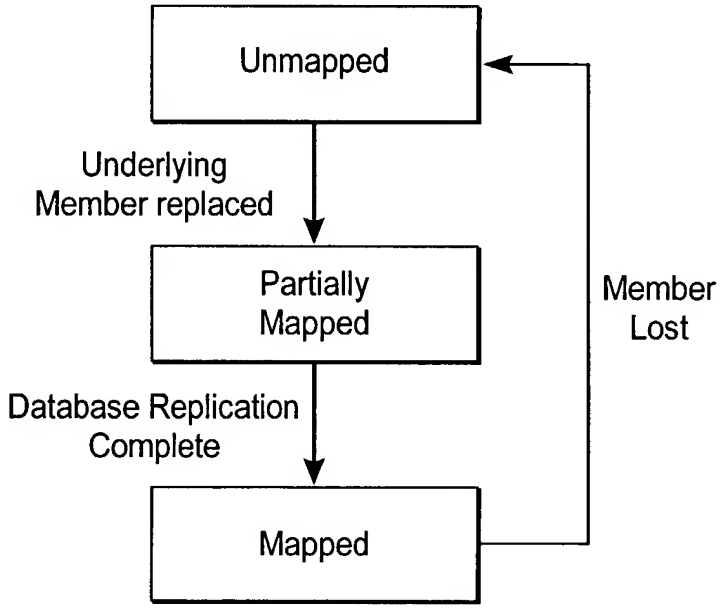


FIG. 6 Member Unit State Diagram

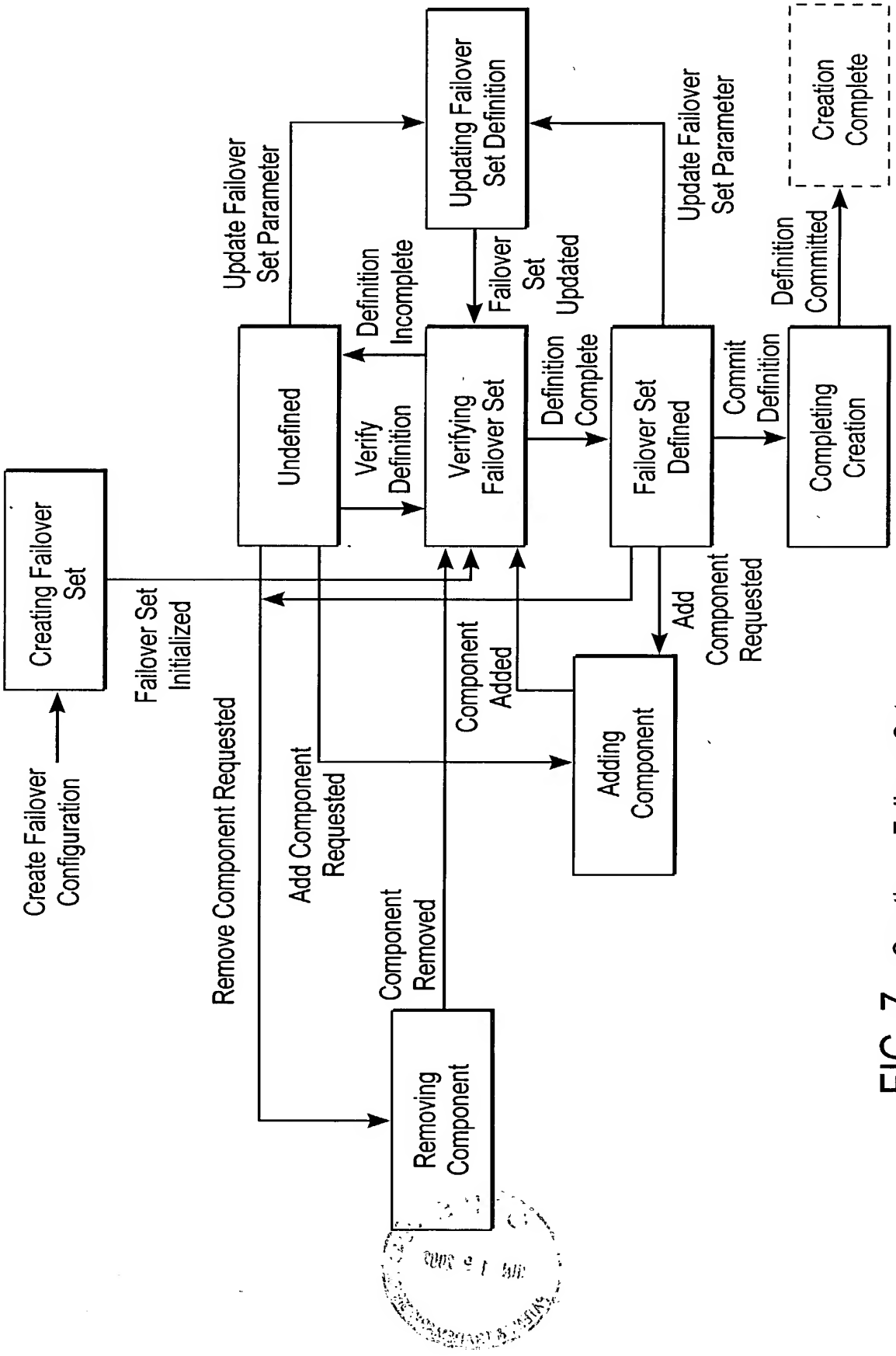


FIG. 7 Creating a Failover Set

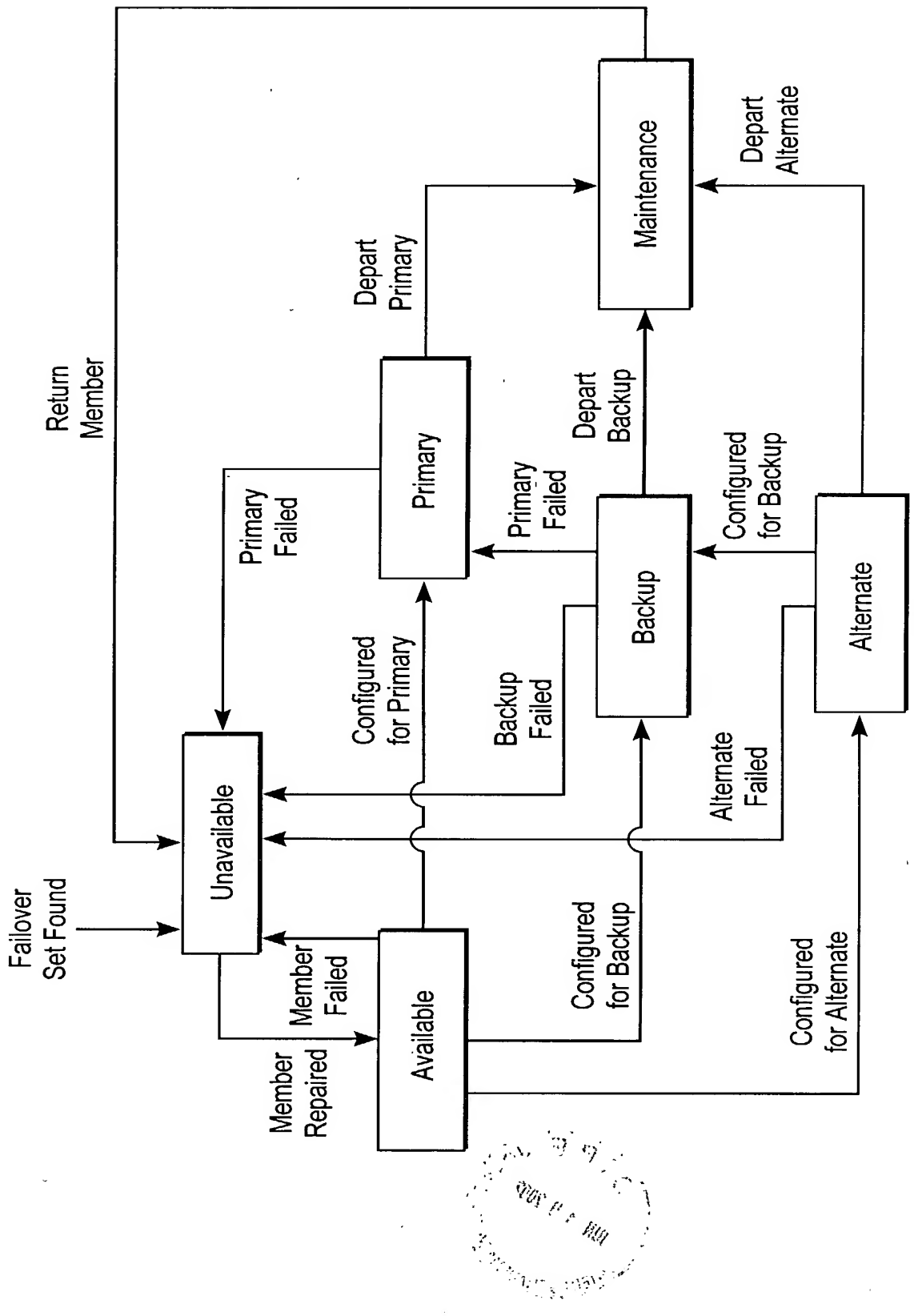


FIG. 8 Member State Diagram

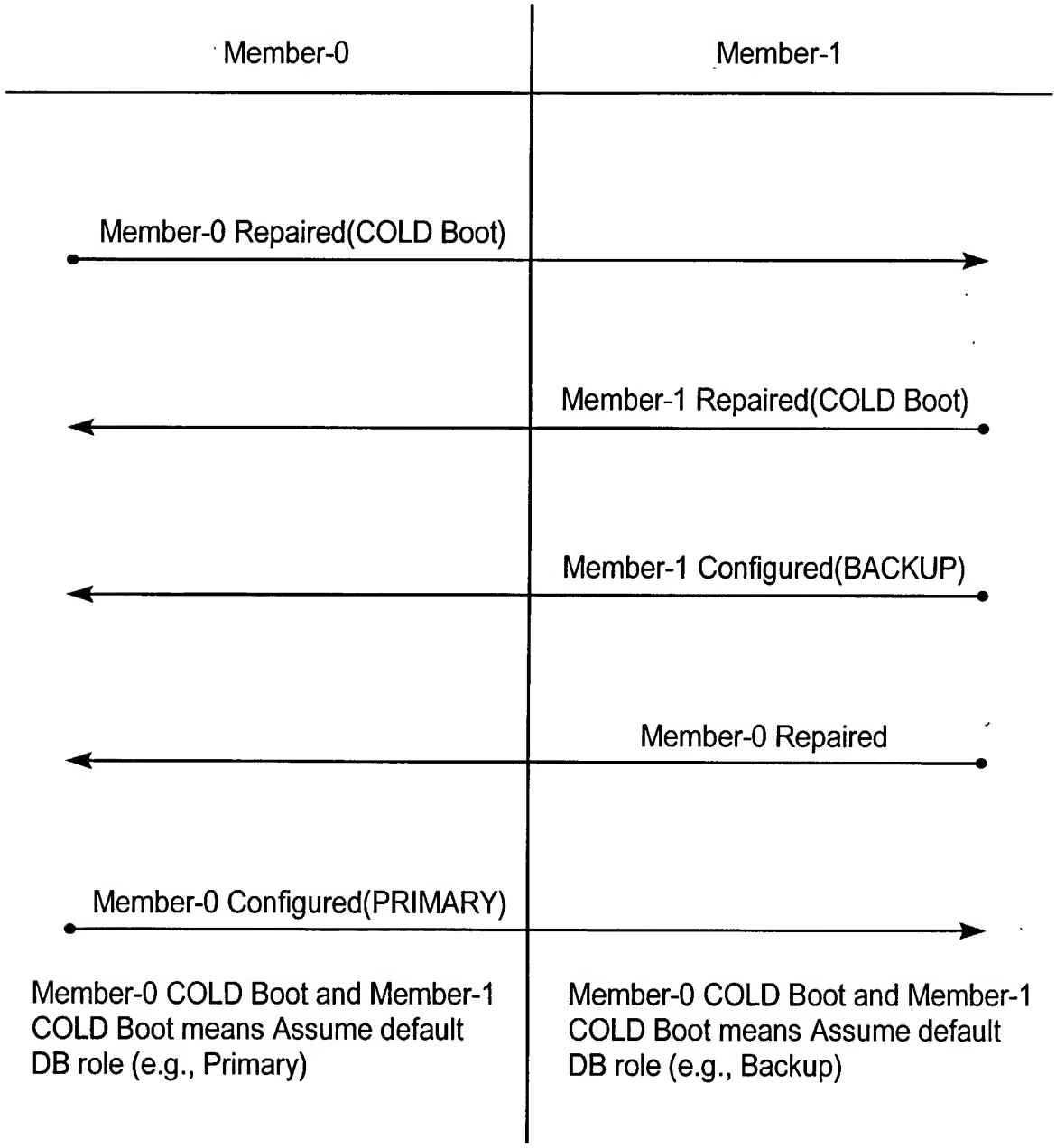


FIG. 9 Member Arbitration for COLD Boot

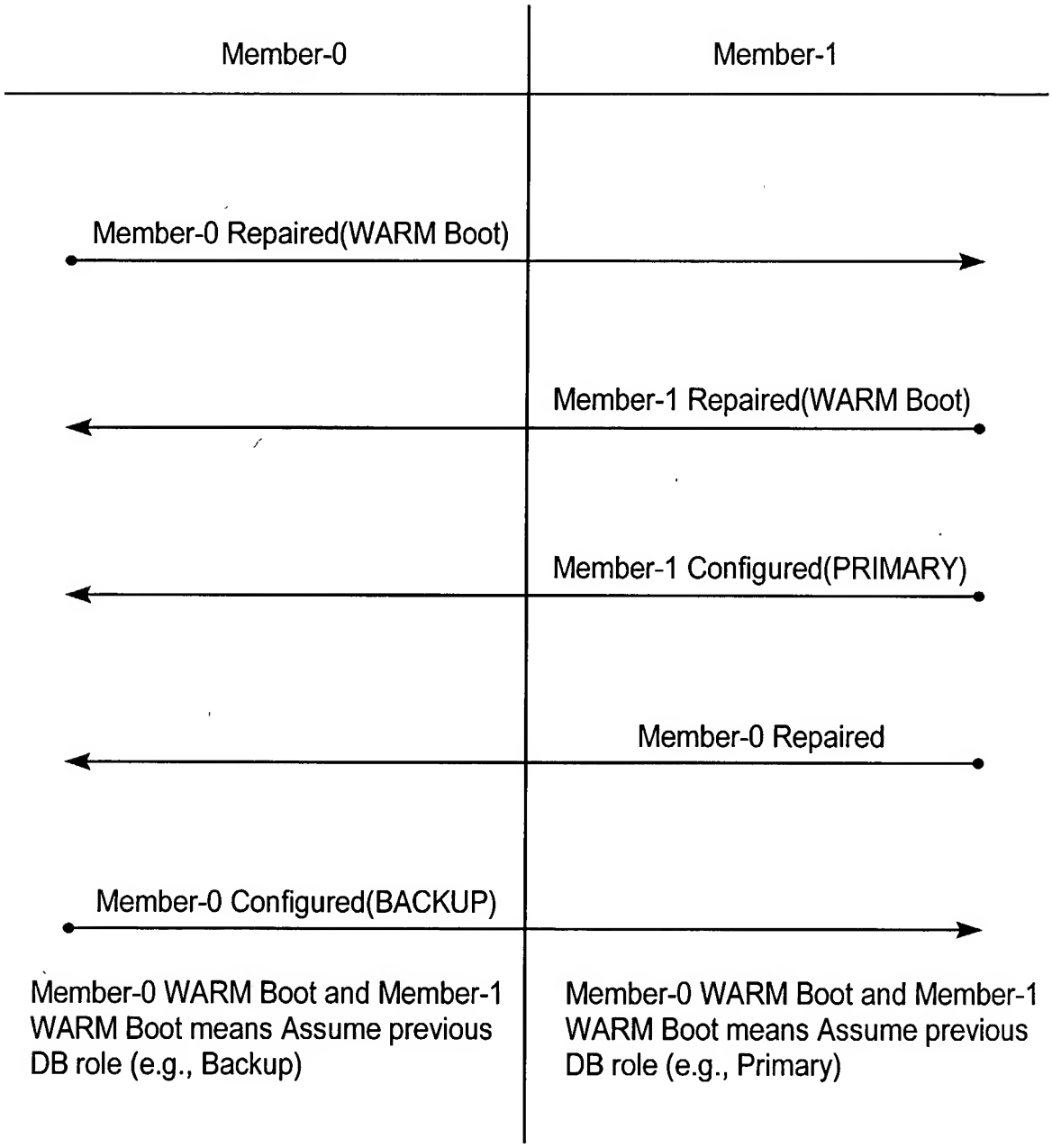


FIG. 10 Member Arbitration for WARM Boot

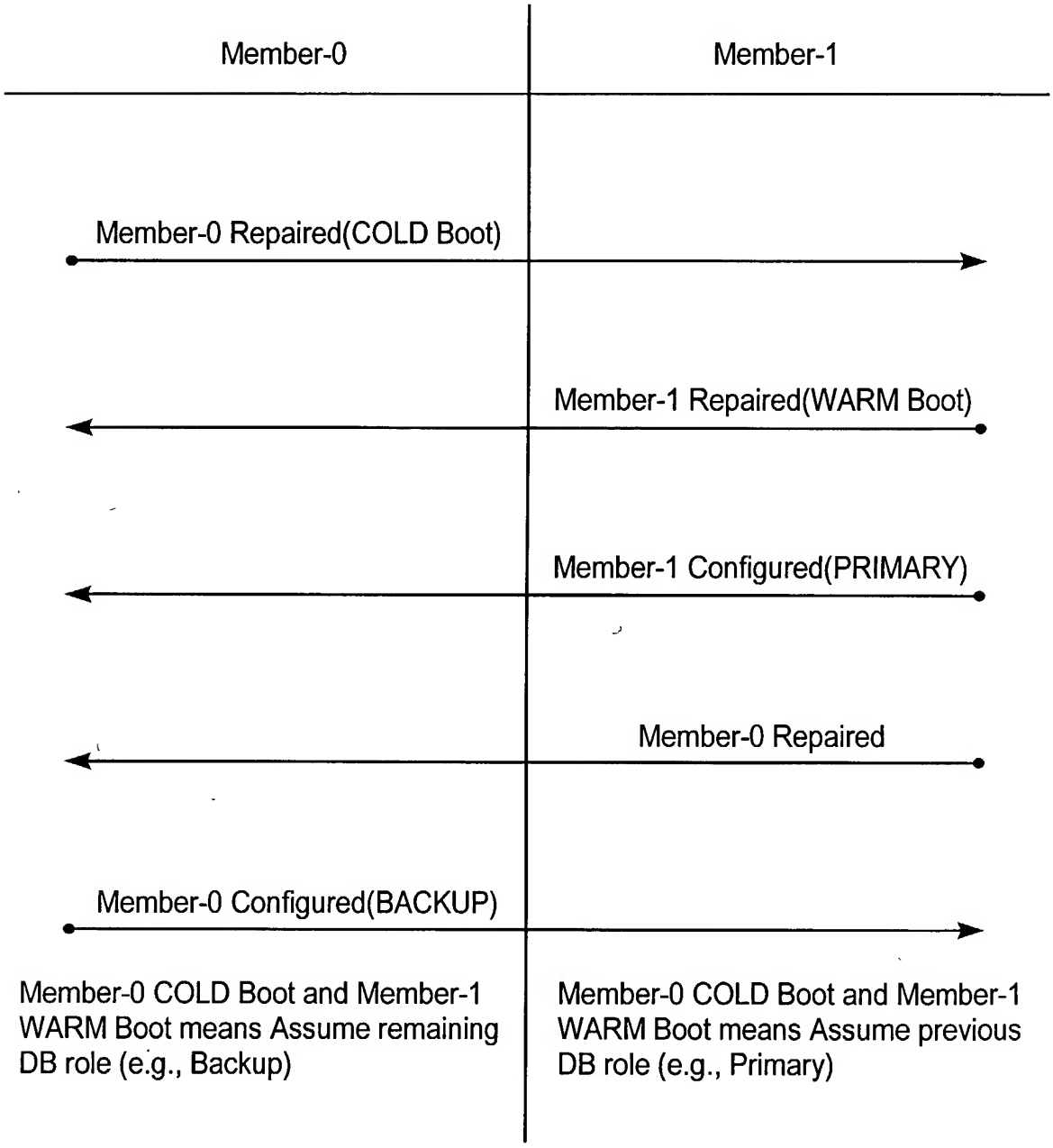


FIG. 11 Member Arbitration for Mixed Boot

	Event					
Old State	Mi Repaired	Mj Repaired	Mi Configured	Mj Configured	Mi Failed	Mj Failed
1. {Mi,Mj} Unavail, {} Avail, {} Primary, {} Backup*	New St: 3 Action: A	New St: 2 Action: B			New St: 1 Action: S	New St: 1 Action: T
2. {Mi} Unavail, {Mj} Avail, {} Primary, {} Backup	New St: 4 Action: C			New St: 8 Action: D	New St: 2 Action: S	
3. {Mj} Unavail, {Mi} Avail, {} Primary, {} Backup		New St: 4 Action: E	New St: 9 Action: F			New St: 3 Action: T
4. {} Unavail, {Mi,Mj} Avail, {} Primary, {} Backup			New St: 7 Action: G	New St: 6 Action: H		
5a. {} Unavail, {} Avail, {Mi} Primary, {Mj} Backup					New St: 8 Action: I	New St: 9 Action: J
5b. {} Unavail, {} Avail, {Mj} Primary, {Mi} Backup					New St: 8 Action: I	New St: 9 Action: J
6. {} Unavail, {Mi} Avail, {Mj} Pri, {} Backup	New St: 6 Action: K		New St: 5a,5b Action: L			New St: 3 Action: M
7. {} Unavail, {Mj} Avail, {Mi} Pri, {} Backup		New St: 7 Action: N		New St: 5a,5b Action: O	New St: 2 Action: P	
8. {Mi} Unavail, {} Avail, {Mj} Pri, {} Backup	New St: 6 Action: C					New St: 1 Action: Q
9. {Mj} Unavail, {} Avail, {Mi} Pri, {} Backup		New St: 7 Action: E			New St: 1 Action: R	
* Initial State						

FIG. 12 2 Member State Table

Action Routines	Description
1	1. Send "Mi repaired" to Mj, if Mj is not failed. 2. Set timer to send "Mi repaired" to Mi
2	1. Send "Mj repaired" to Mi, if Mi is not failed. 2. Set timer to send "Mj repaired" to Mj
A	1. If Mi and configured send "Mi configured" to Mj. 2. Set timer to send "Mi configured" to Mi. 3.
B	1. If Mj and configured send "Mj configured" to Mi. 2. Set timer to send "Mj configured" to Mj. 3.
C	1. If Mj, echo event back to Mi. 2. If Mi and configured send "Mi configured" to Mj. 3. Set timer to
D	1. If Mj, become Primary. 2. Otherwise, nop.
E	1. If Mi, echo event back to Mj. 2. If Mj and configured send "Mj configured" to Mi. 3. Set timer to
F	1. If Mi, become Primary. 2. Otherwise, nop.
G	1. If Mi, become Primary. 2. Otherwise, echo event back to Mi.
H	1. If Mj, become Primary. 2. Otherwise, echo event back to Mj.
I	1. If Mj, become Primary. 2. If Mi become Backup.
J	1. If Mi, become Primary. 2. If Mj become Backup.
K	1. If Mj, echo event back to Mi. 2. Otherwise, nop
L	1. If Mj, determine Member Role. 2. SEnd "Mi configured" to Mi when done. 3. If Mi determine
M	1. If Mj, perform Fail-Stop processing. 2. Send "Mj Failed" to Mi. 3. Otherwise become Primary after
N	1. If Mi, echo event back to Mj. 2. Otherwise, nop
O	1. If Mi, determine Member role. 2. Send "Mj configured" to Mj when done. 3. If Mj determine
P	1. If Mi, perform Fail-Stop processing. 2. Send "Mi Failed" to Mj. 3. Otherwise become Primary after
Q	1. If Mj, perform Fail-Stop processing for Mj. 2. Otherwise nop.
R	1. If Mi, perform Fail-Stop processing for Mi. 2. Otherwise nop.
S	1. Perform Fail-Stop processing for Mi
T	1. Perform Fail-Stop processing for Mj

FIG. 13 Action Routines for a 2 Node Configuration

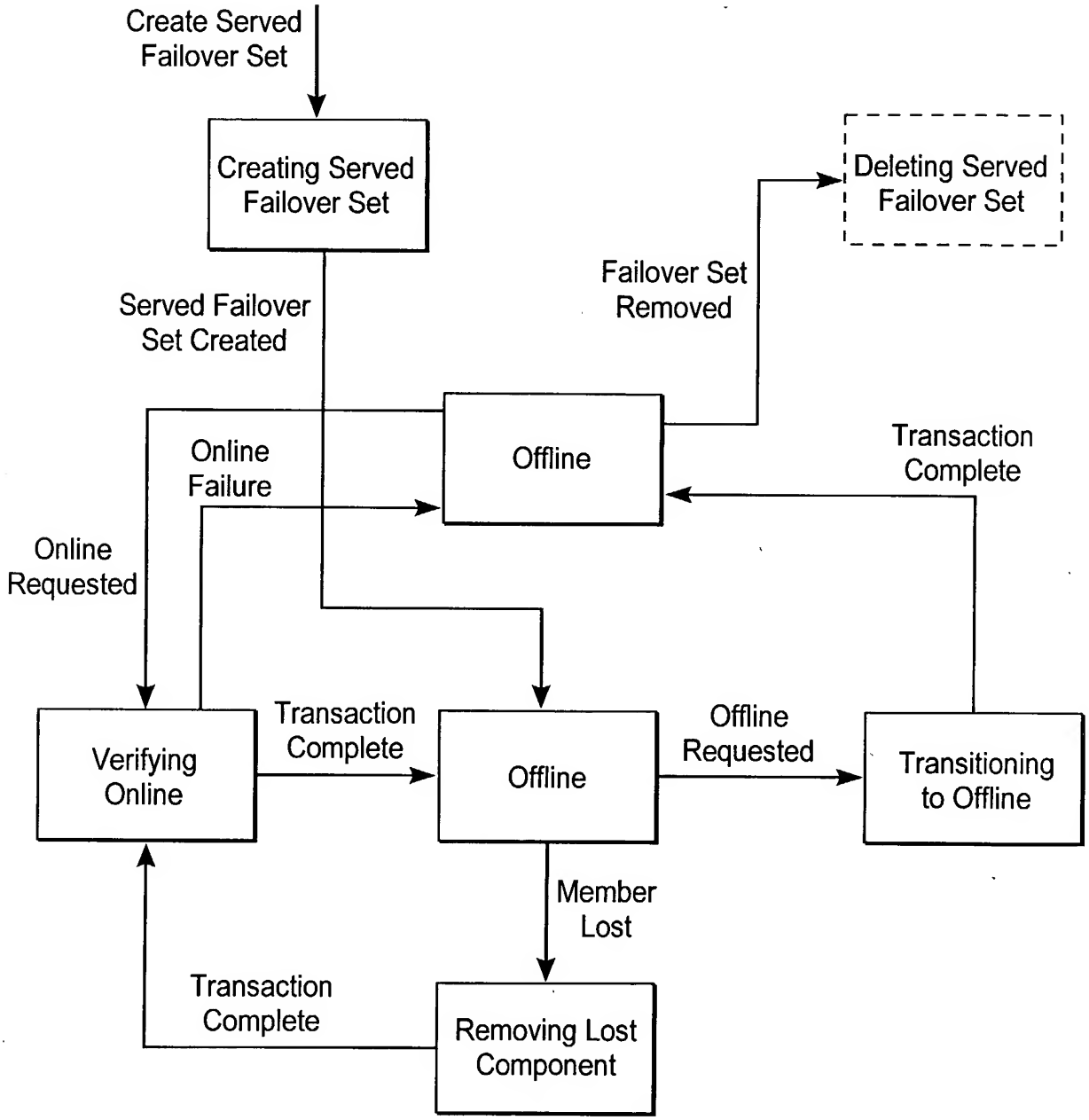


FIG. 14 Served Failover Set State Machine Diagram

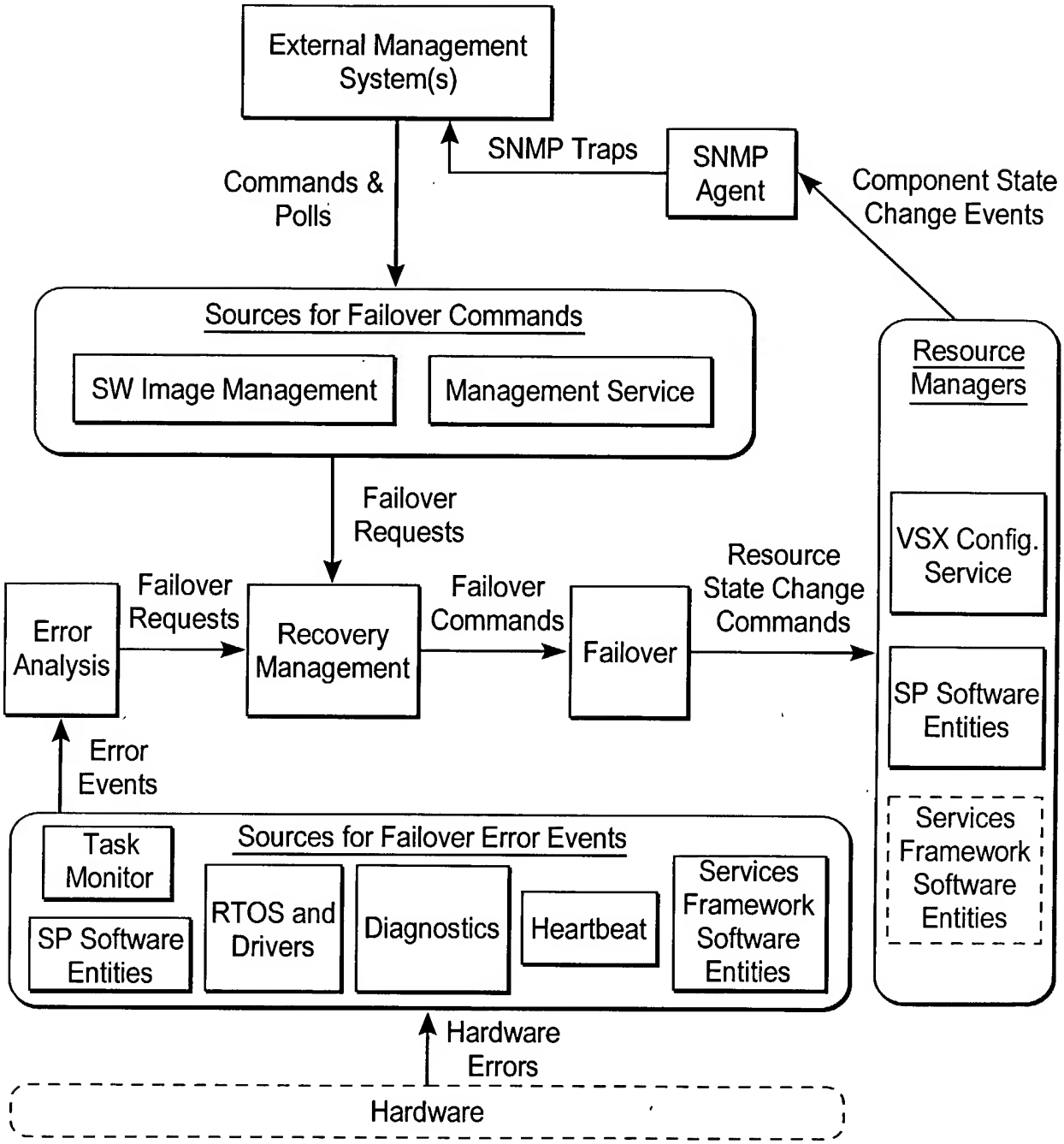
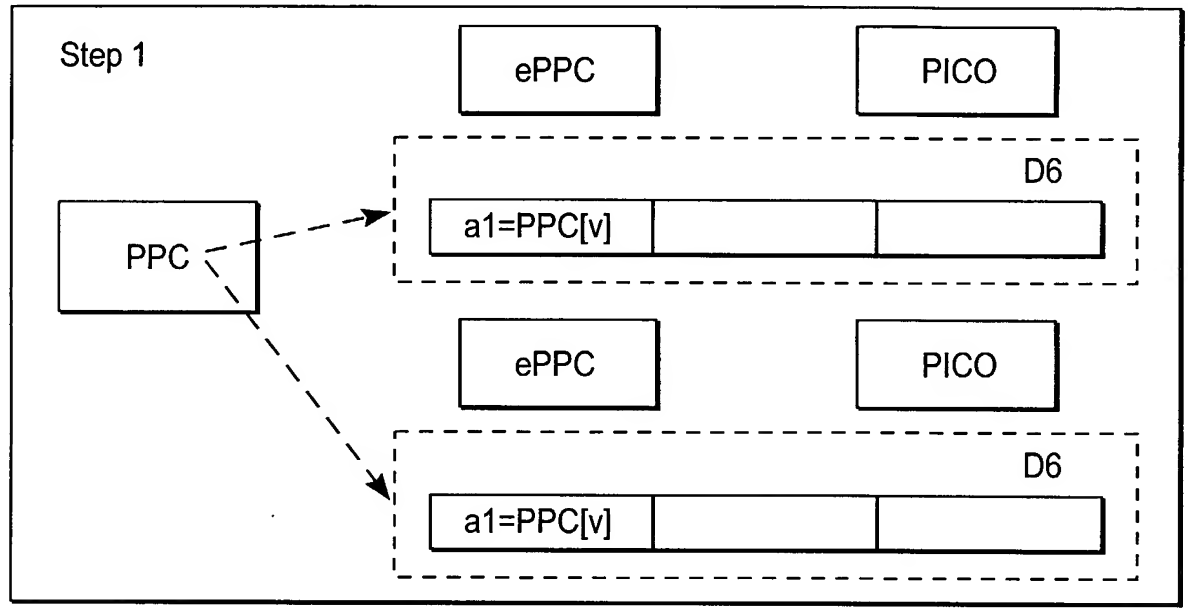
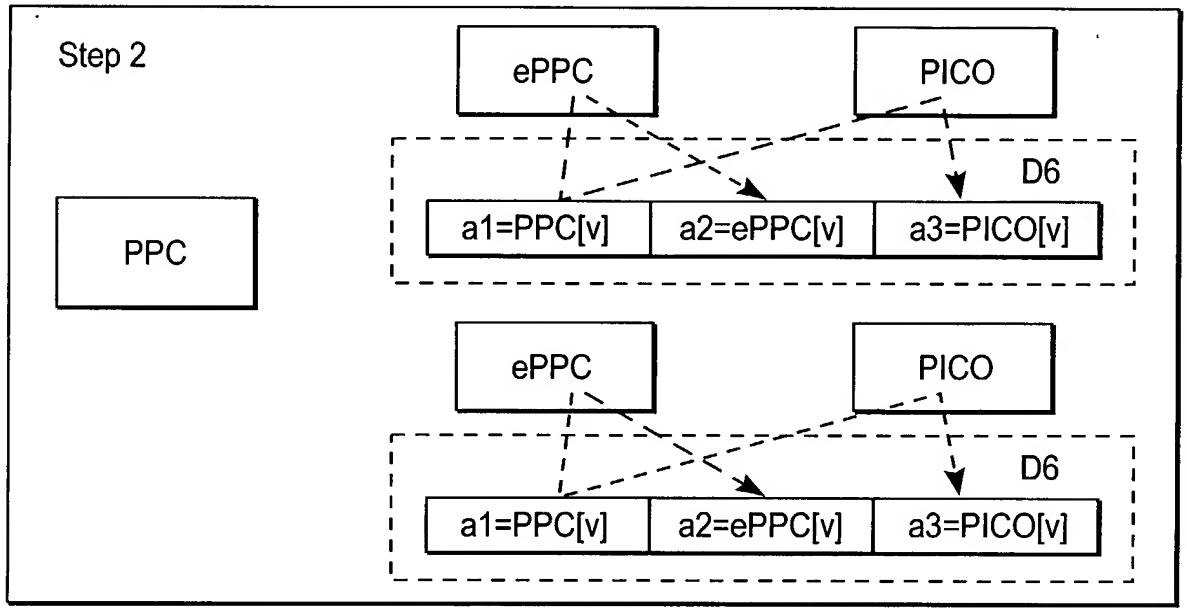


FIG. 15 Fault Detection and Analysis Architecture

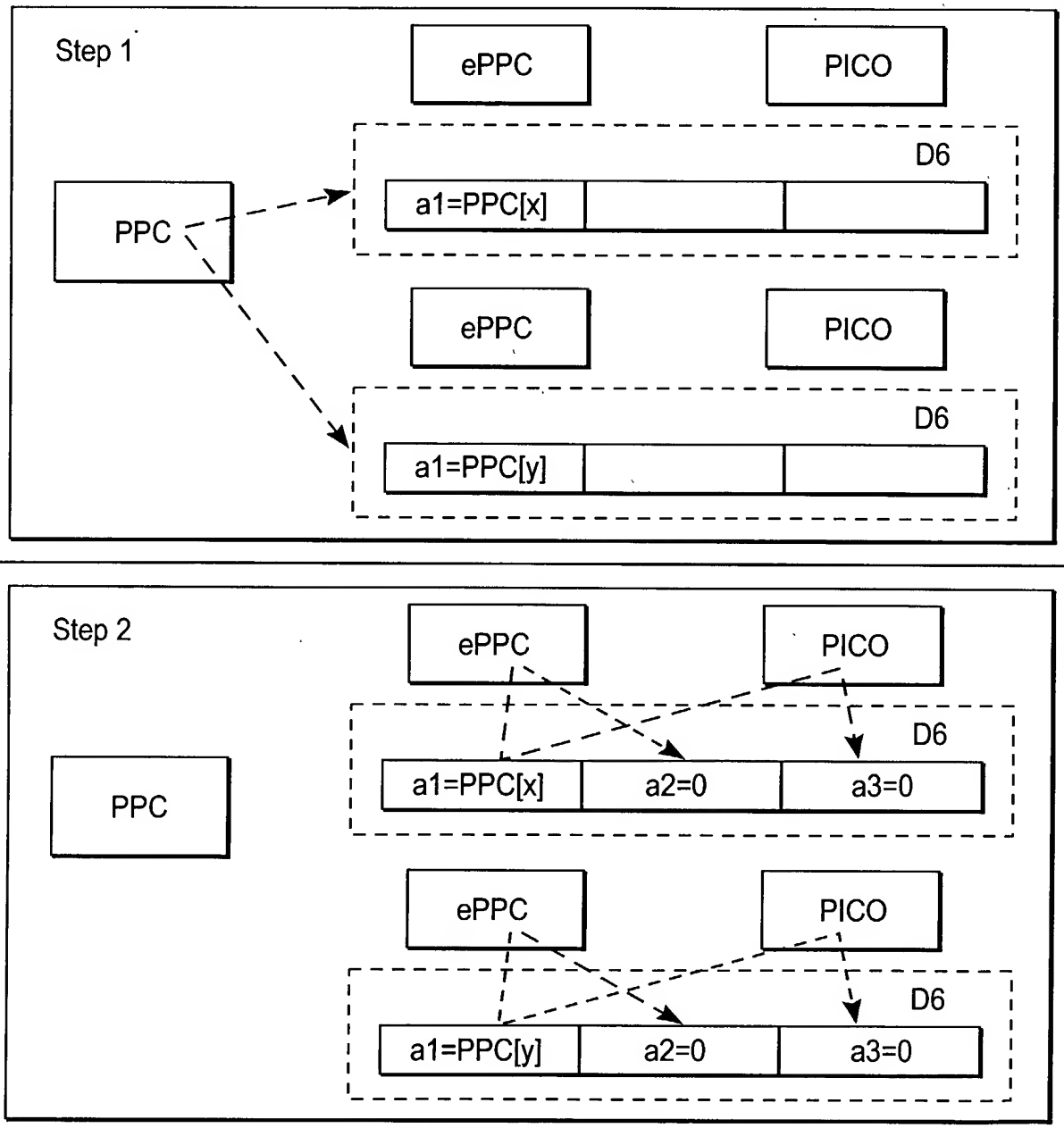




Step 3

majority(a1,a2,a3) = majority(v,v,v) = v, No faults

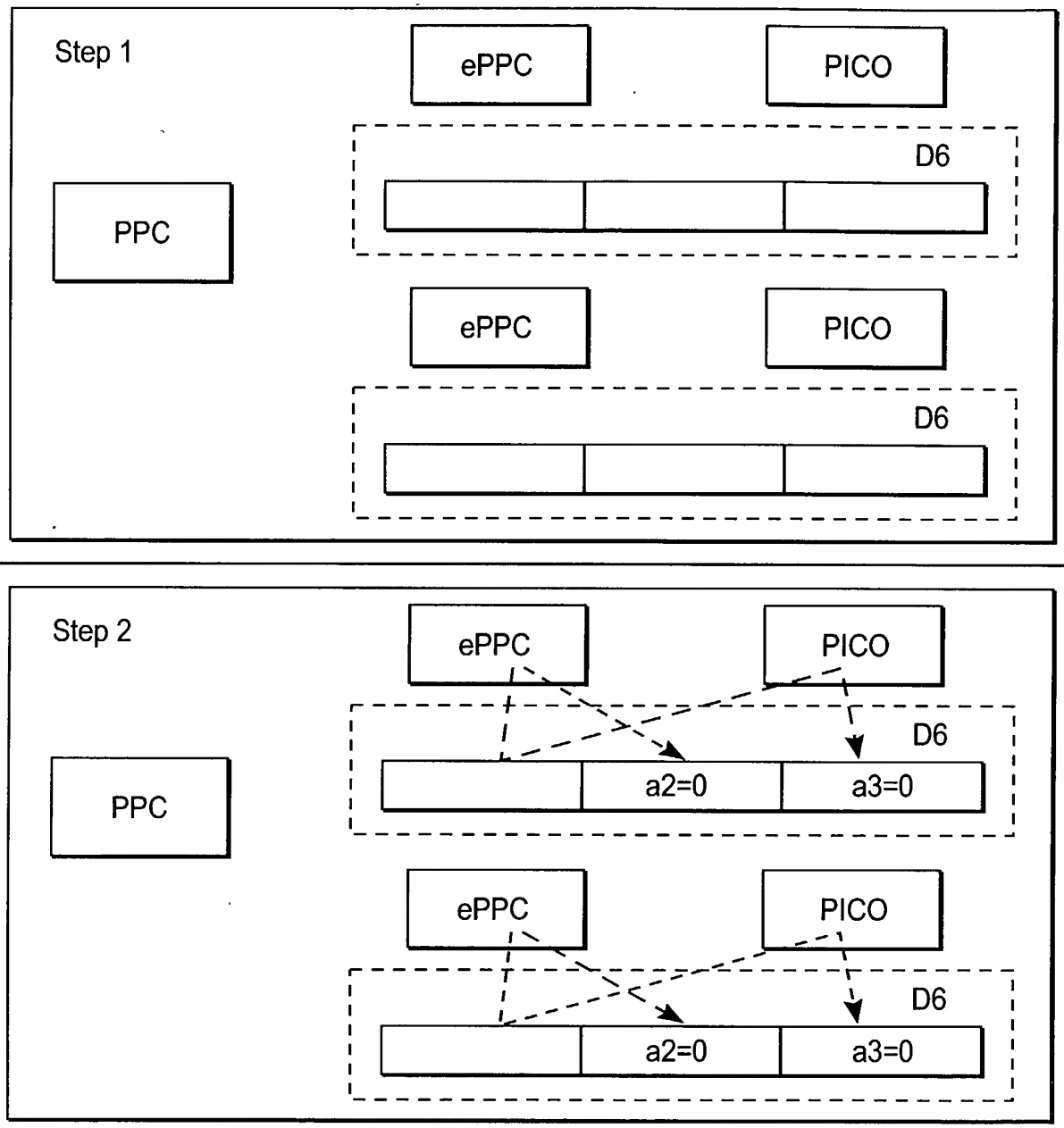
FIG. 16 No Faults



Step 3

majority(a1,a2,a3) = majority(x,0,0) = 0, transmitter fault

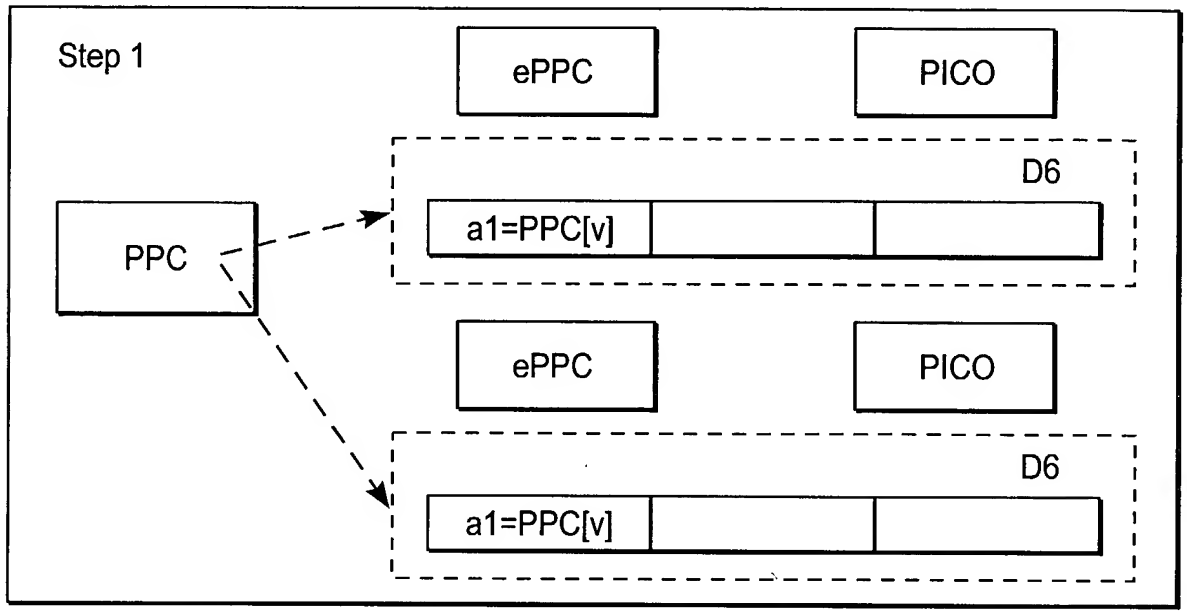
FIG. 17 Transmitter fault (sends a bad value)

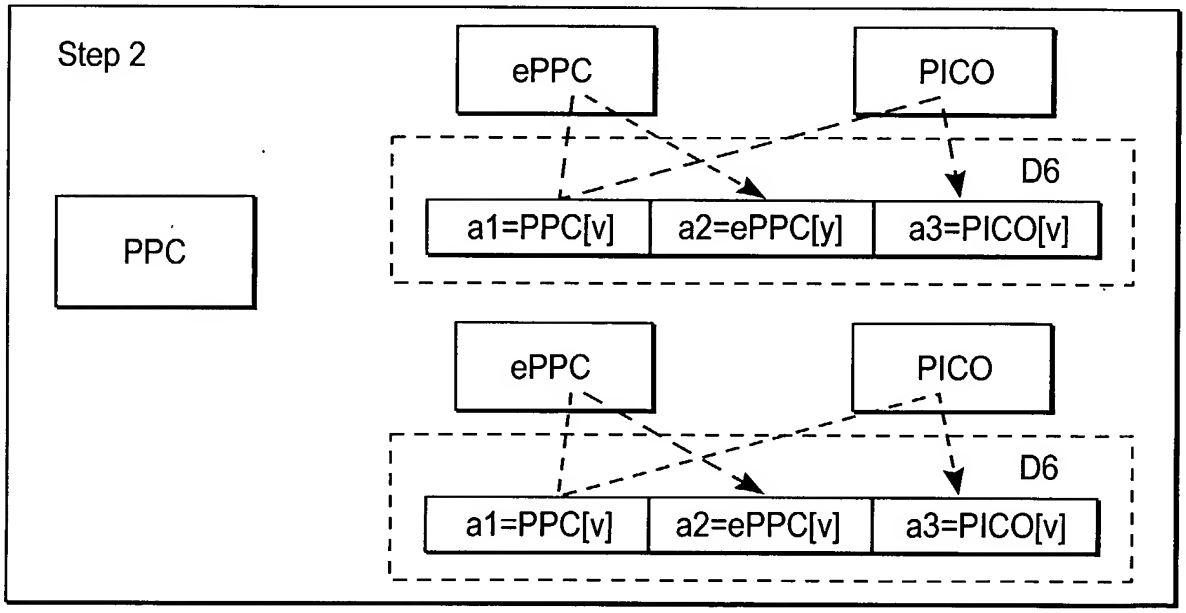


Step 3

majority(a1,a2,a3) = majority(0,0,0) = 0, transmitter fault

FIG. 18 Transmitter fault (doesn't send a value)

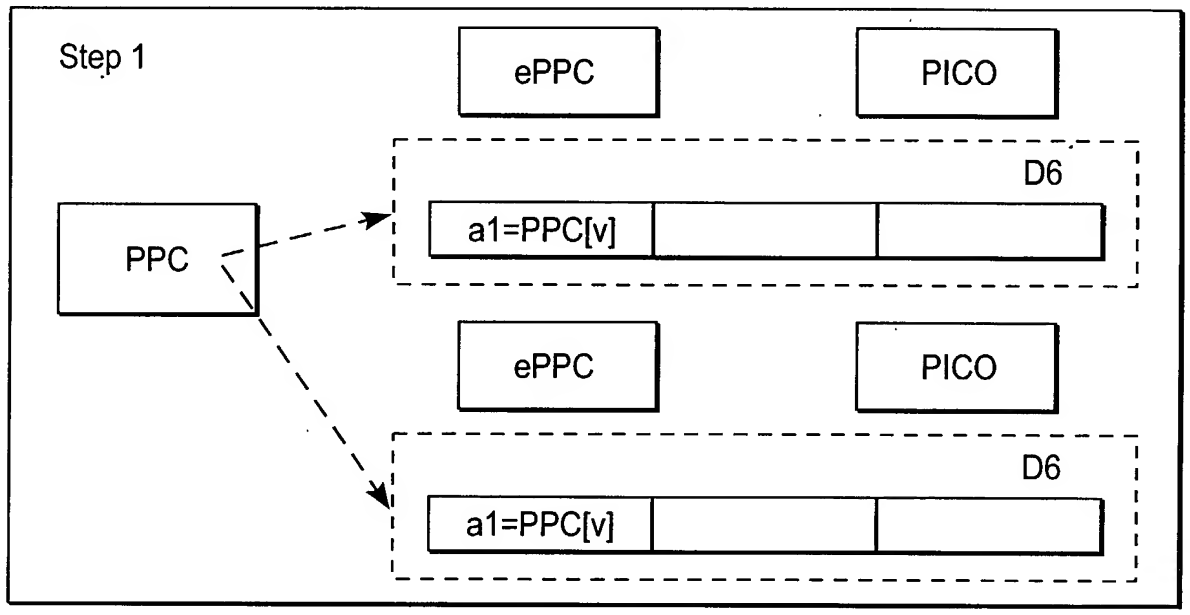


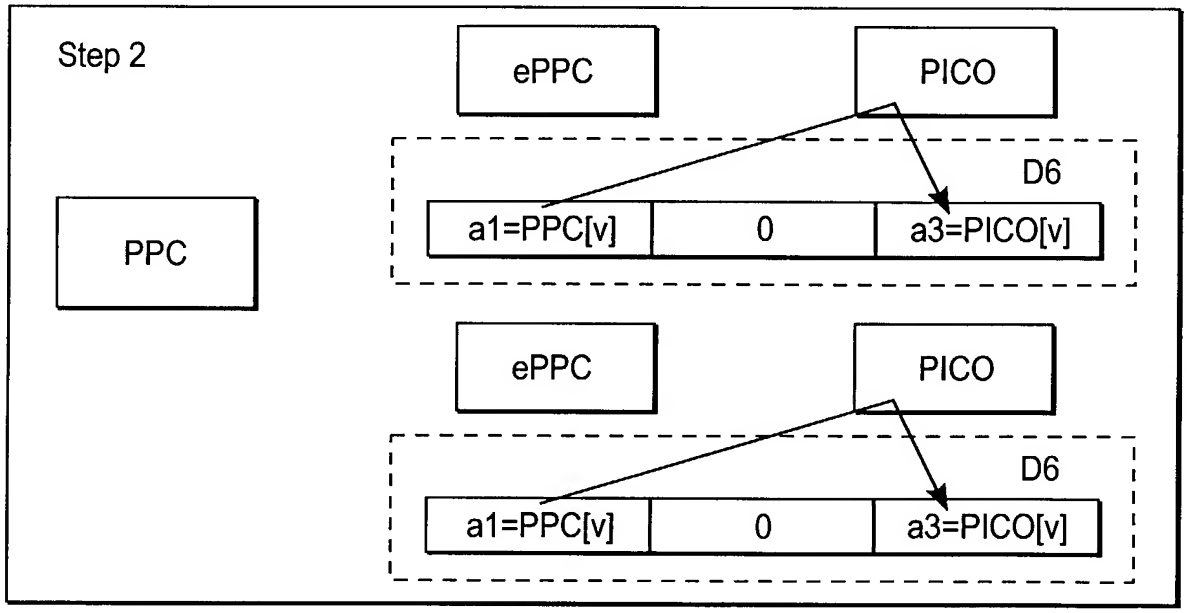


Step 3

majority(a1,a2,a3) = majority(v,y,v) = v, Receiver fault

FIG. 19 Receiver fault (relays wrong value)





Step 3

majority(a1,a2,a3) = majority(v,0,v) = v, Receiver fault

FIG. 20 Receiver fault (doesn't relay a value)

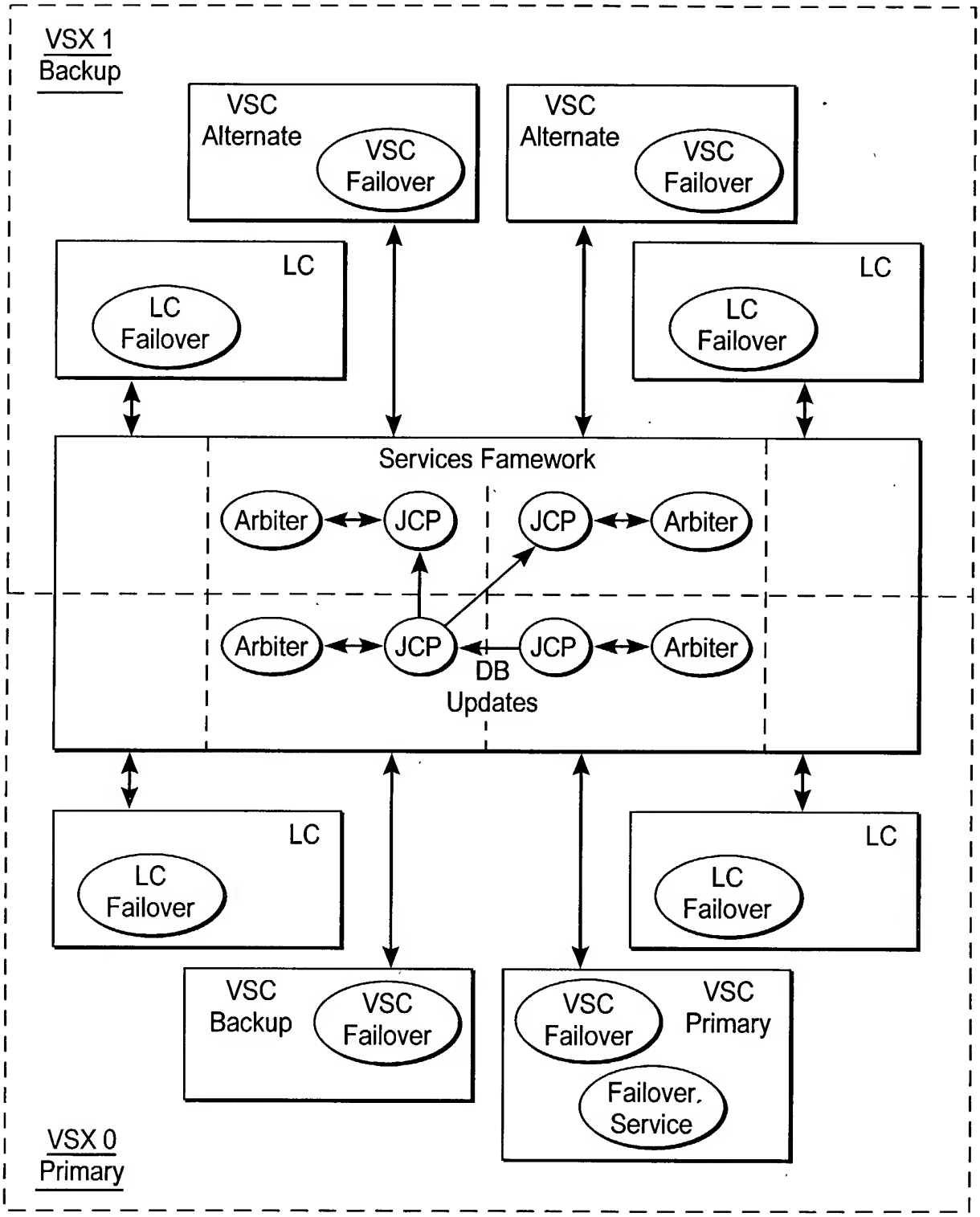


FIG. 21A Failover Service Architecture

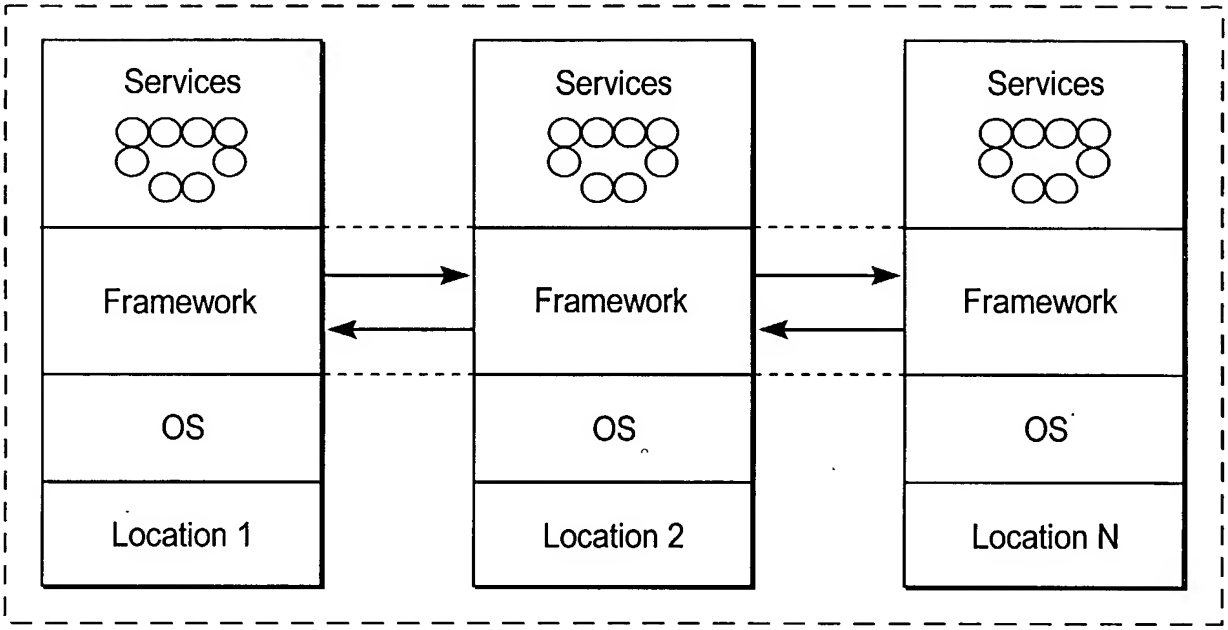


FIG. 21B

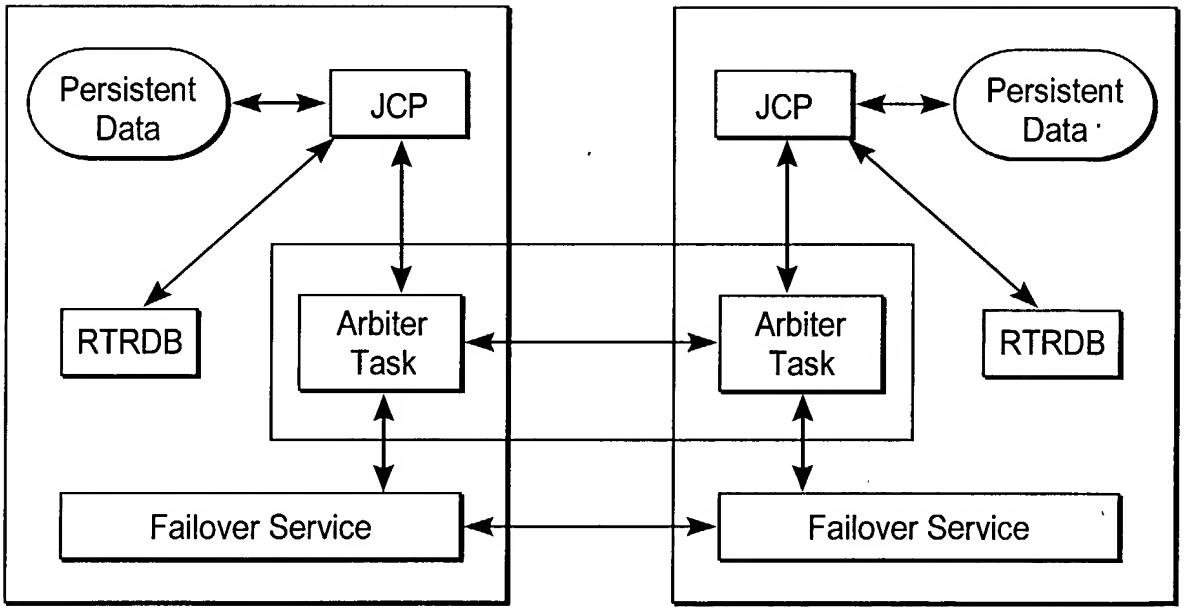


FIG. 22 An Arbiter for the Database

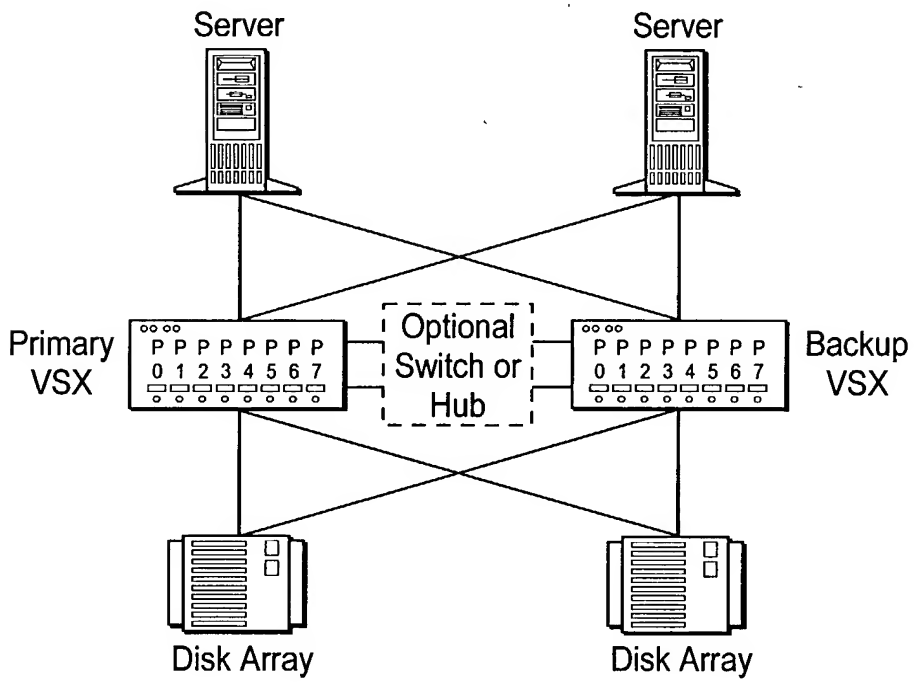


FIG. 23 Shared Link

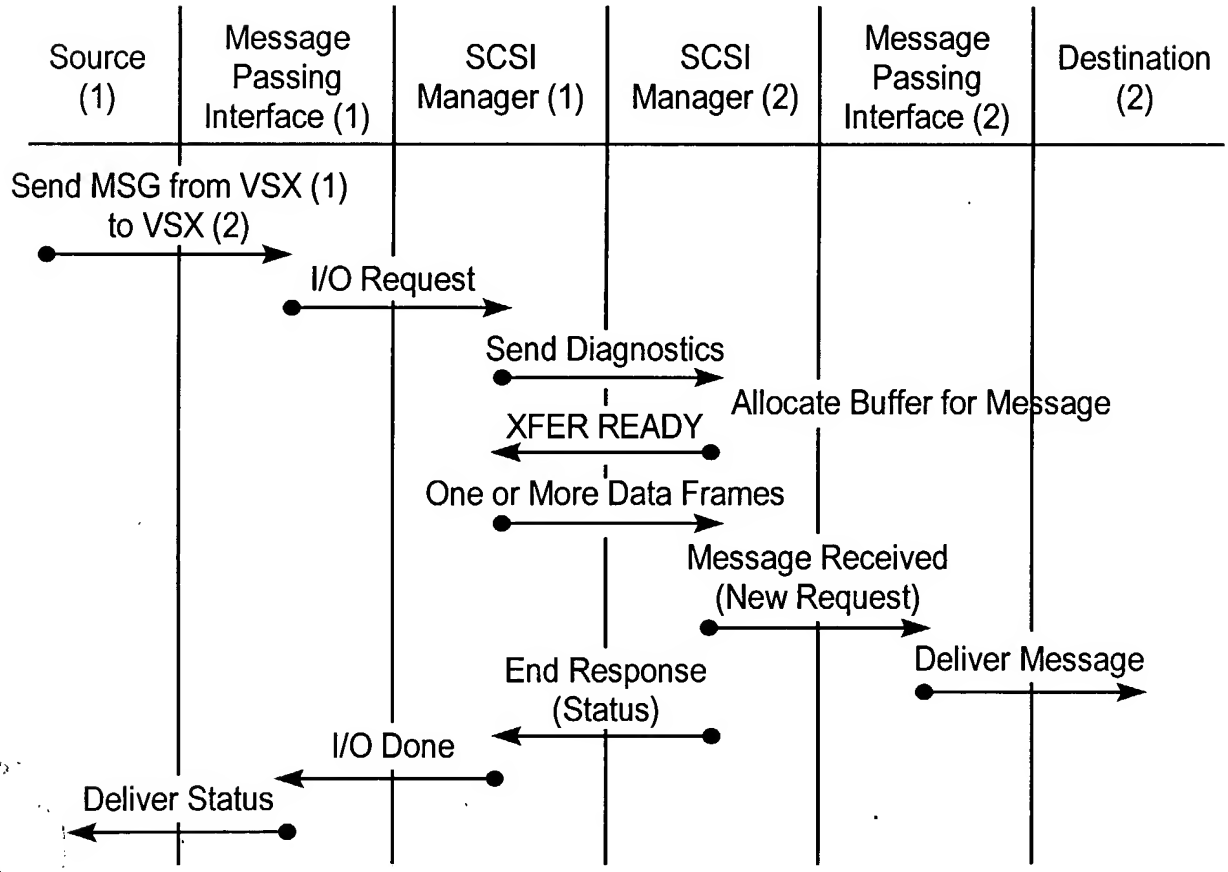


FIG. 24 VSX to VSX Message Passing

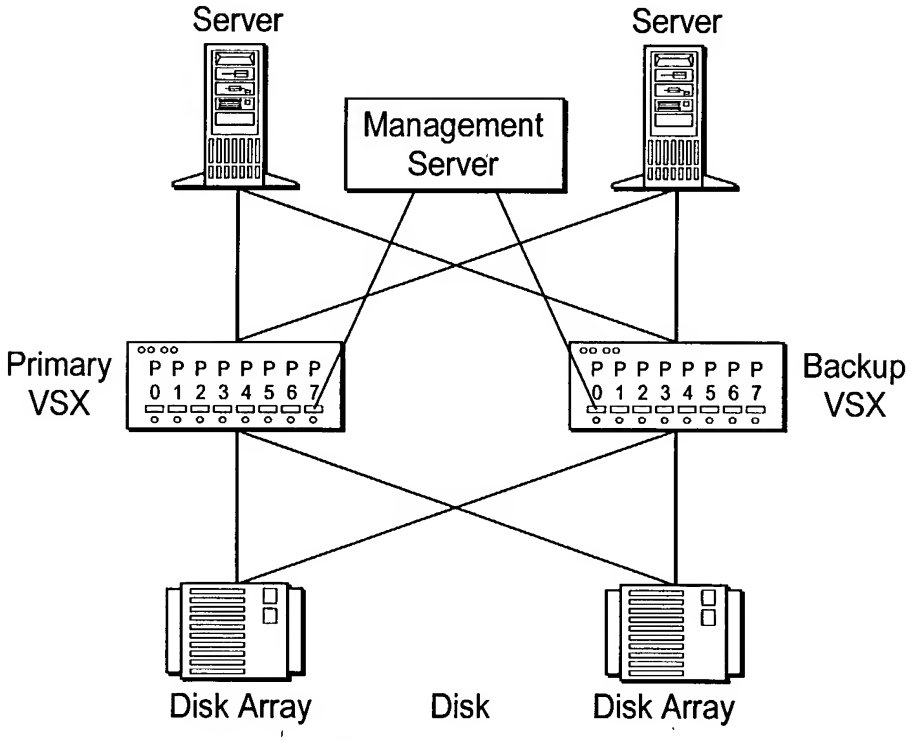


FIG. 25 Management Link

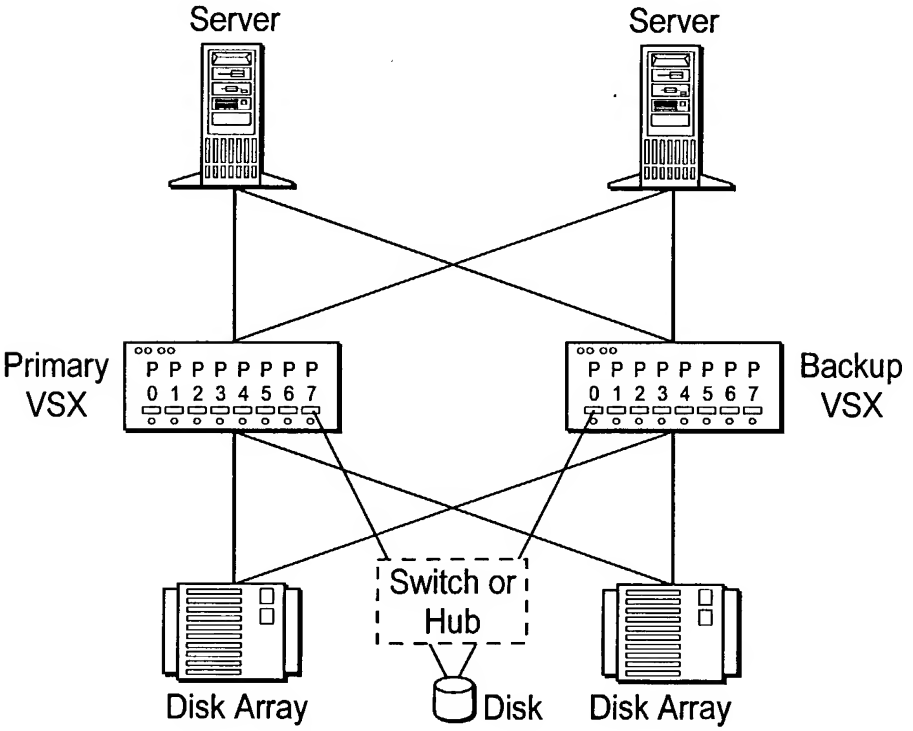


FIG. 26 Shared Disk

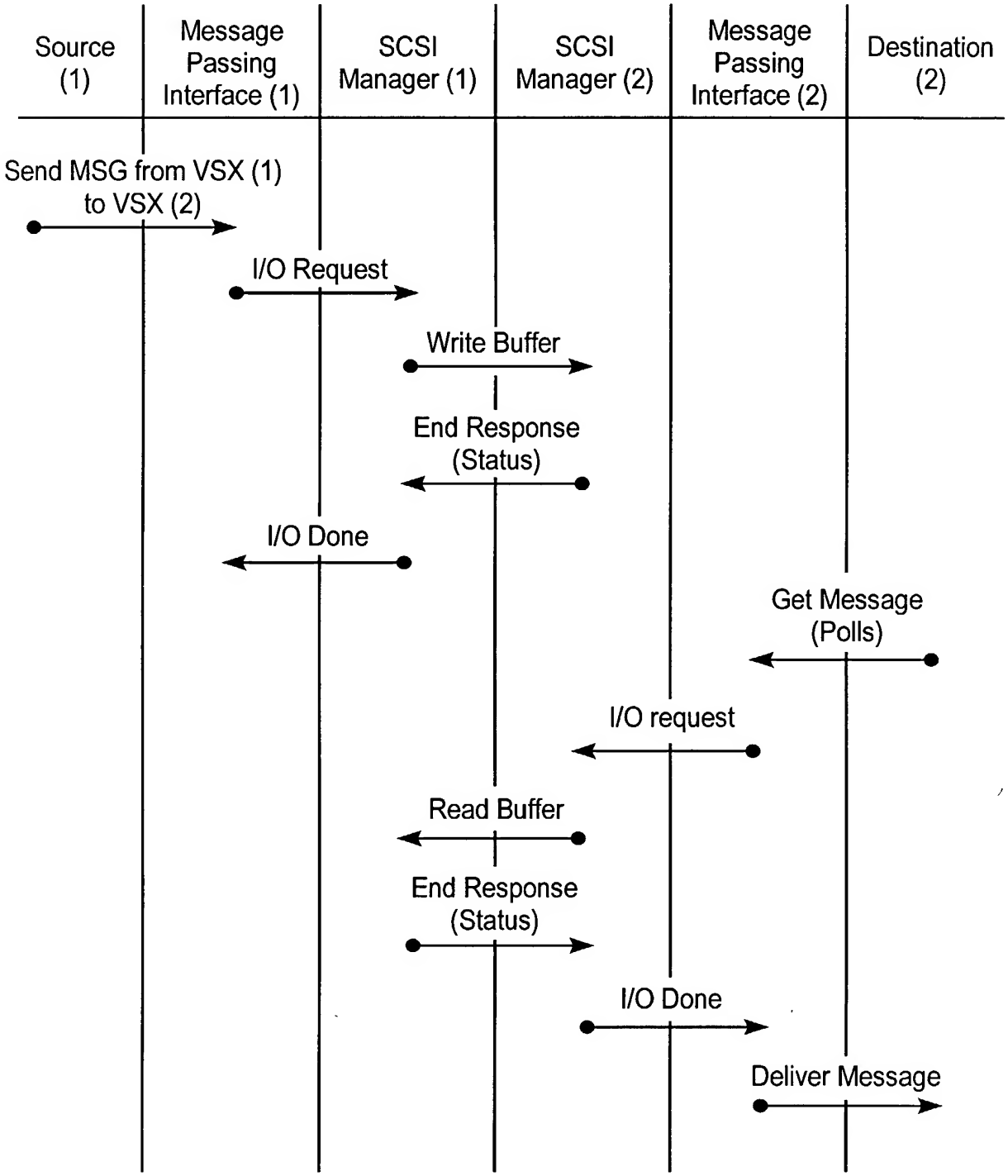


FIG. 27 VSX to VSX Communication Using Shared Disk

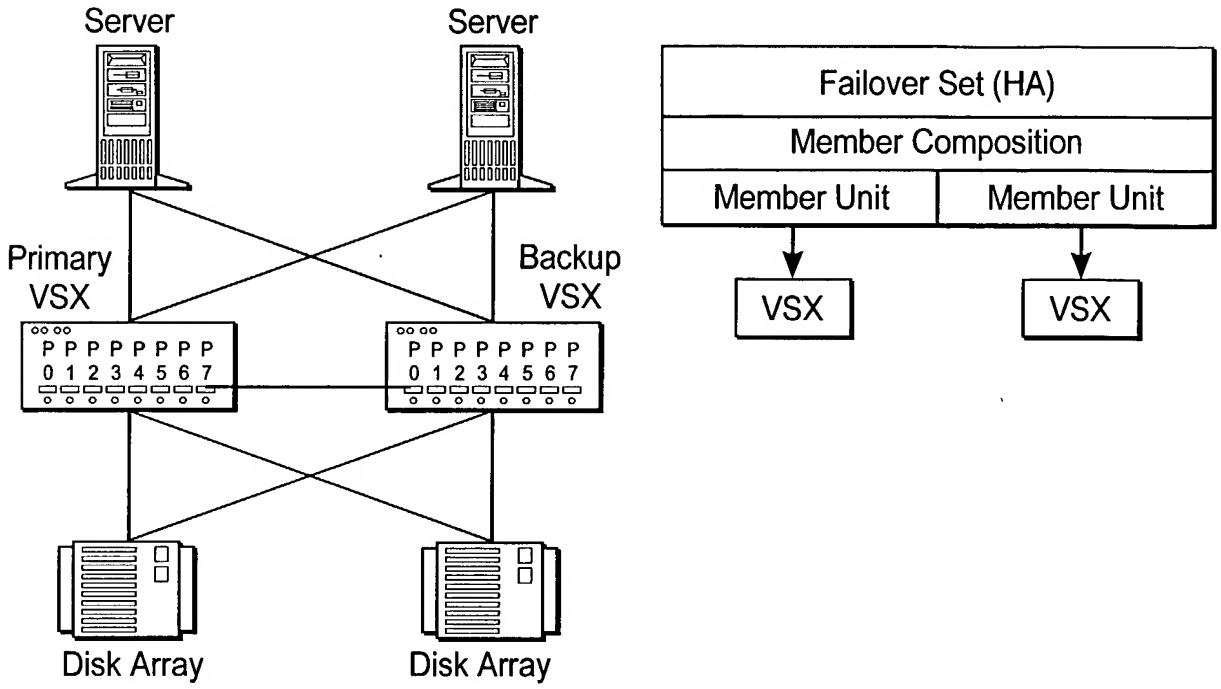


FIG. 28 2 Node HA Configuration

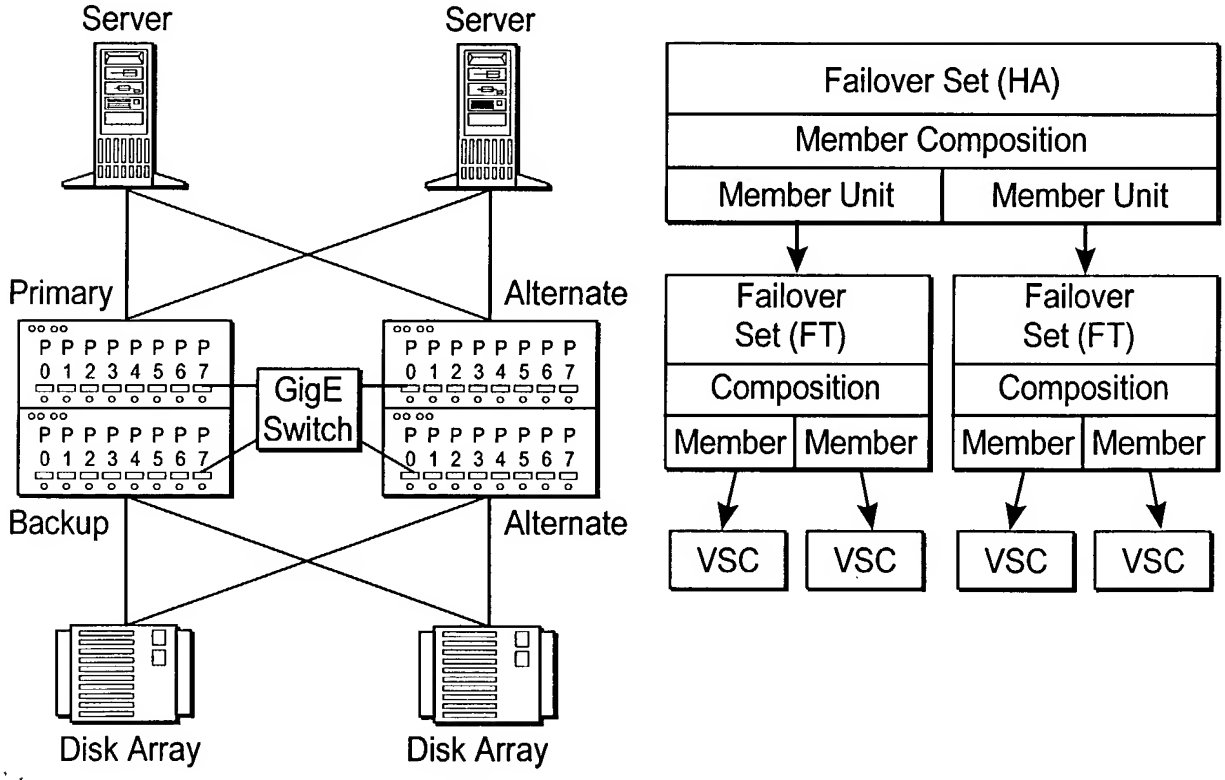
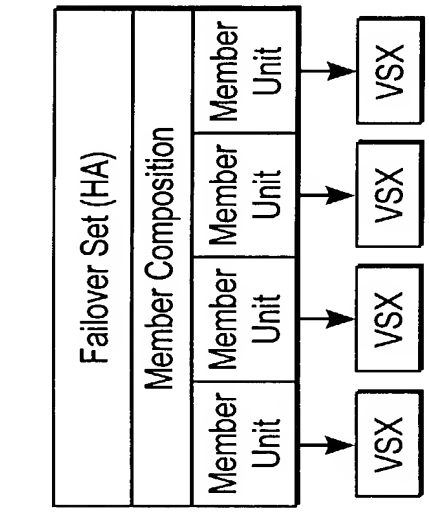


FIG. 29 Hierarchical HA Configuration



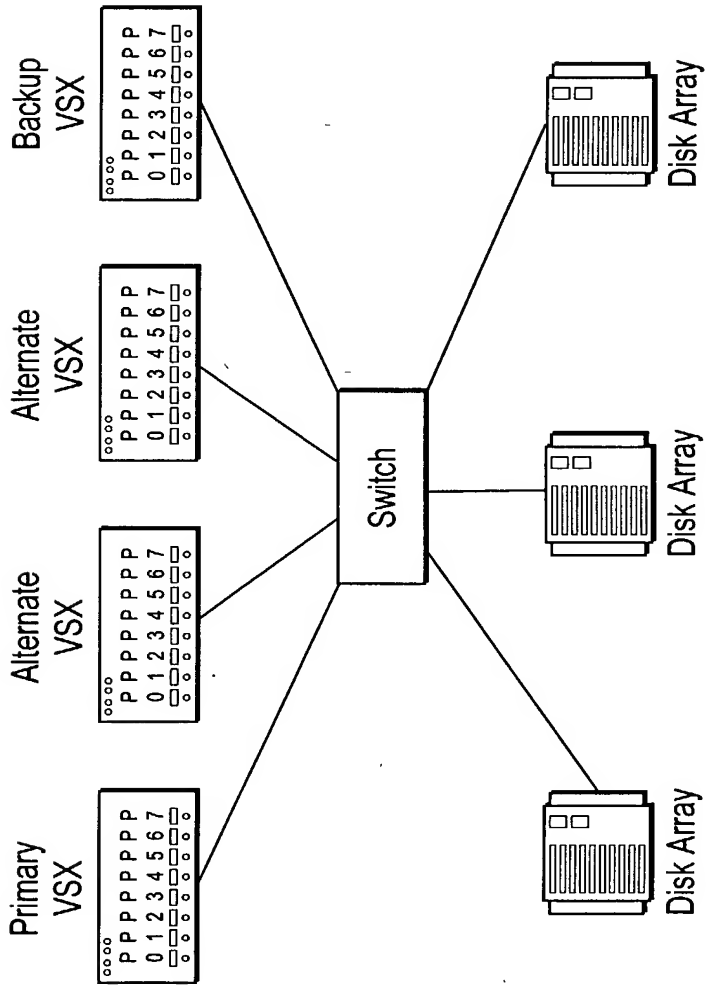
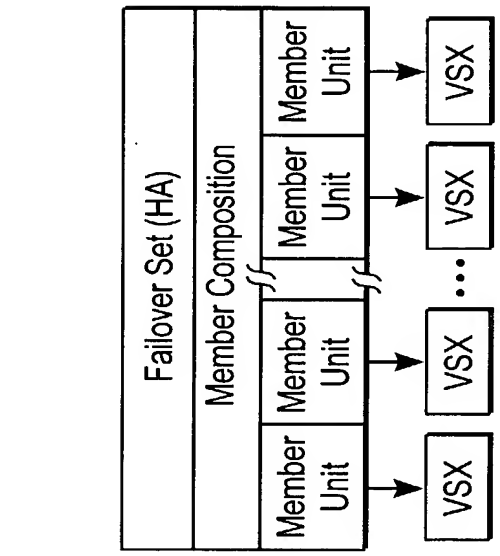


FIG. 30 N + 1 Nodes



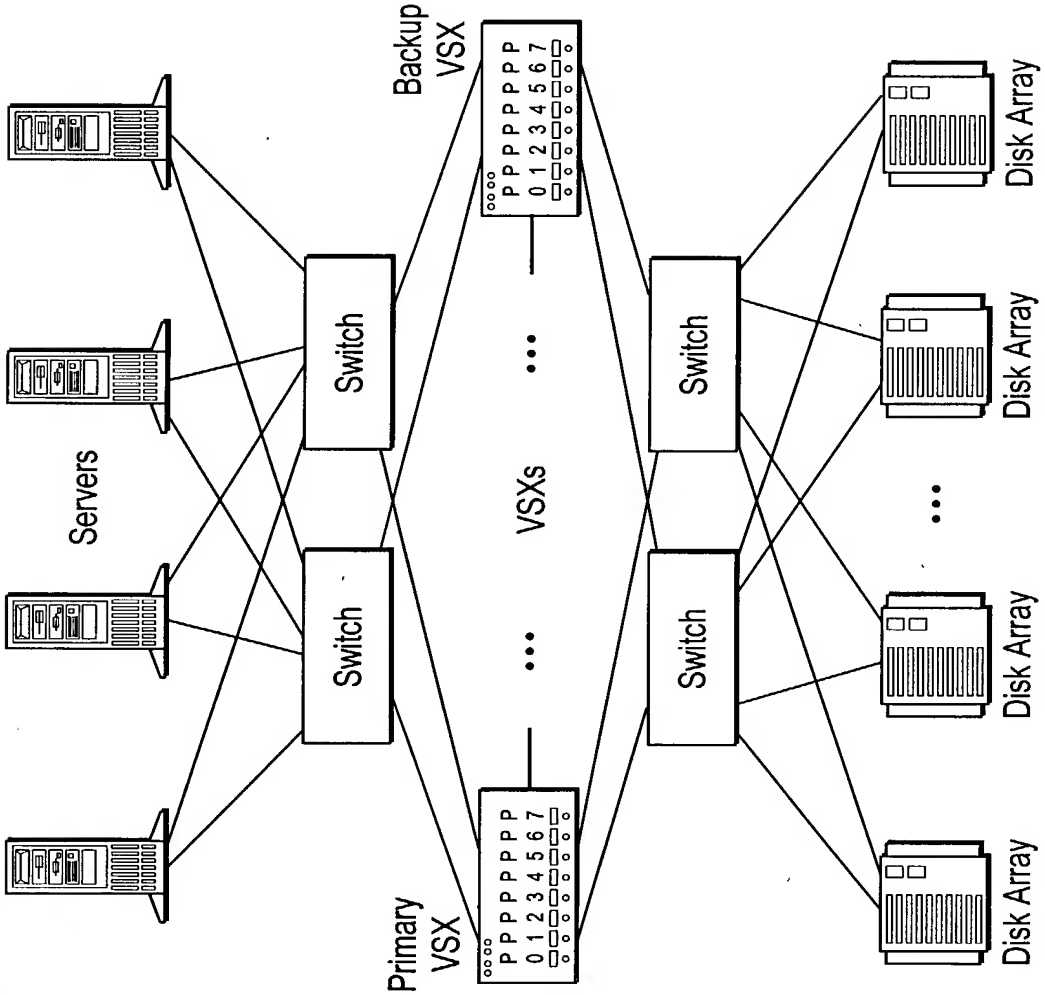
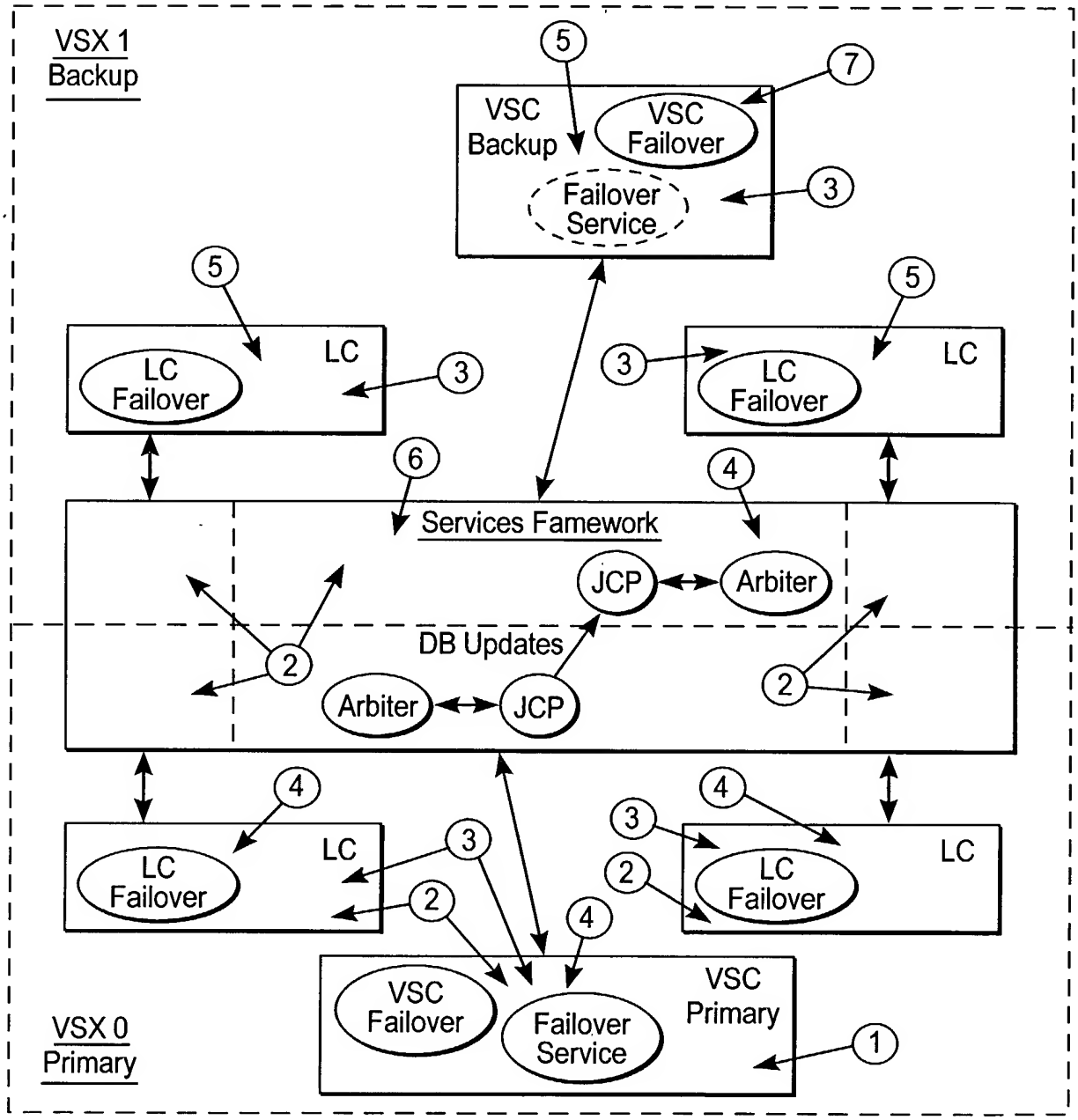
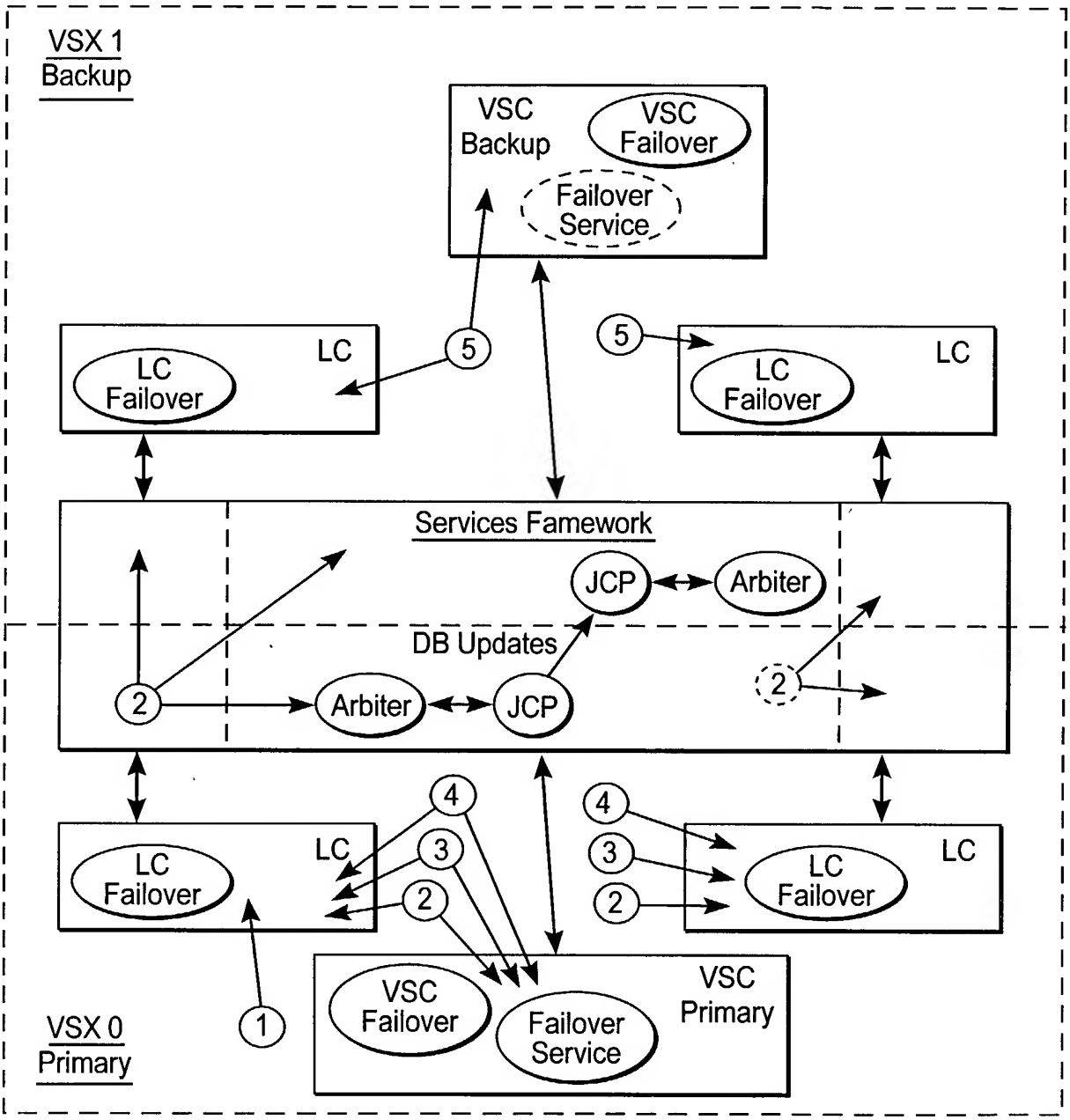


FIG. 31 N – Nodes



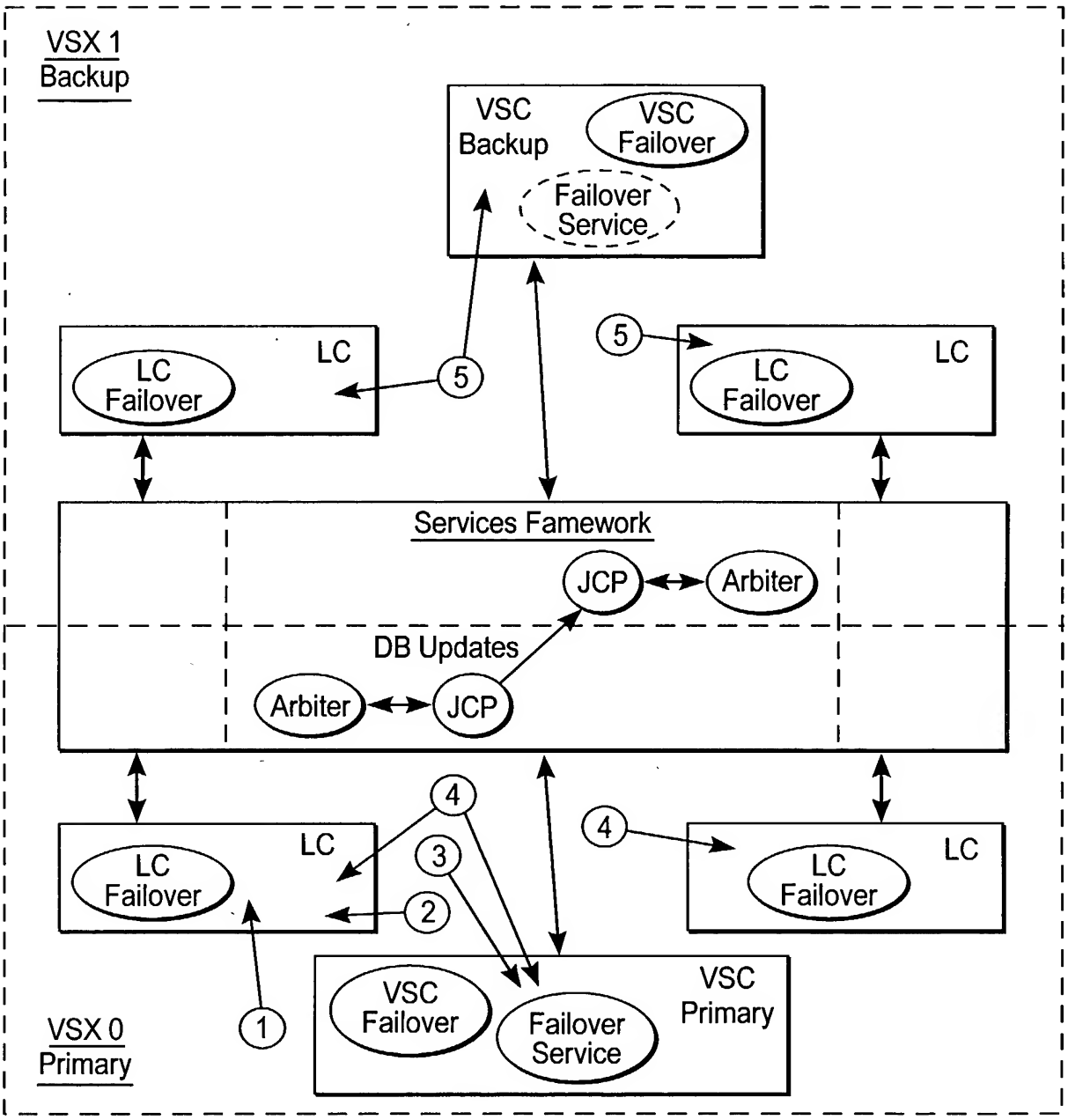
1. VSC Crashes (Host Processor)
2. Rest of system detects VSC crash
3. Error Analysis determines Member fails, which translates into a "Primary Lost" event
4. Activate JCP in Master mode and enable the virtual services, Stop Ports on failed Primary
5. Reset affected devices, Cleanup reservations and locks, Set Unit Attention
6. Restart management requests
7. Restart RCON and FORMAT

FIG. 32 VSX Failover, Primary Fails



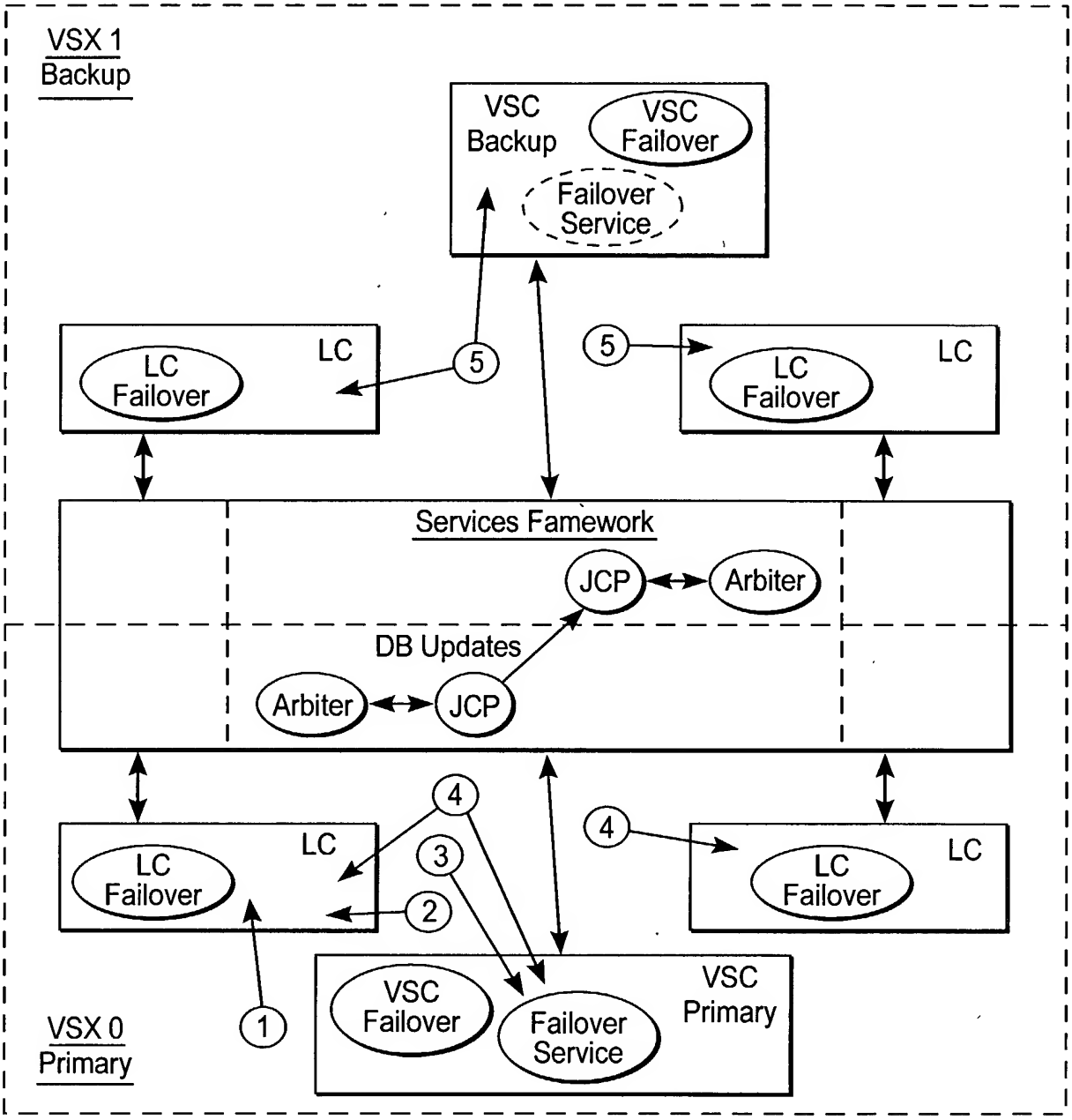
1. LC Crashes (Host Processor)
2. Rest of system detects LC crash
3. Error Analysis determines IO Path fails for all devices (server and storage) on LC
4. Upstream hLUNs report CHECK CONDITION for all devices connected to ports on failed LC. RCON and FORMAT aborted, if necessary.
5. Restart RCON and FORMAT, if necessary

FIG. 33 IO Path Failover - LC Fails



1. FC ASIC Crashes
2. LC detects FC ASIC crash
3. Error Analysis determines IO Path fails for all devices (server or storage) on FC ASIC
4. Upstream hLUNs report CHECK CONDITION for all devices connected to failed FC Ports. RCON and FORMAT aborted, if necessary.
5. Restart RCON and FORMAT, if necessary

FIG. 34 IO Path Failover - FC Port Fails



1. Link down on port
2. LC detects FC Port link down
3. Error Analysis determines IO Path fails for all devices (server or storage) on FC Port
4. Upstream hLUNs report CHECK CONDITION for all devices connected to FC Port. RCON and FORMAT aborted, if necessary.
5. Restart RCON and FORMAT, if necessary

FIG. 35 IO Path Failover - Link Down

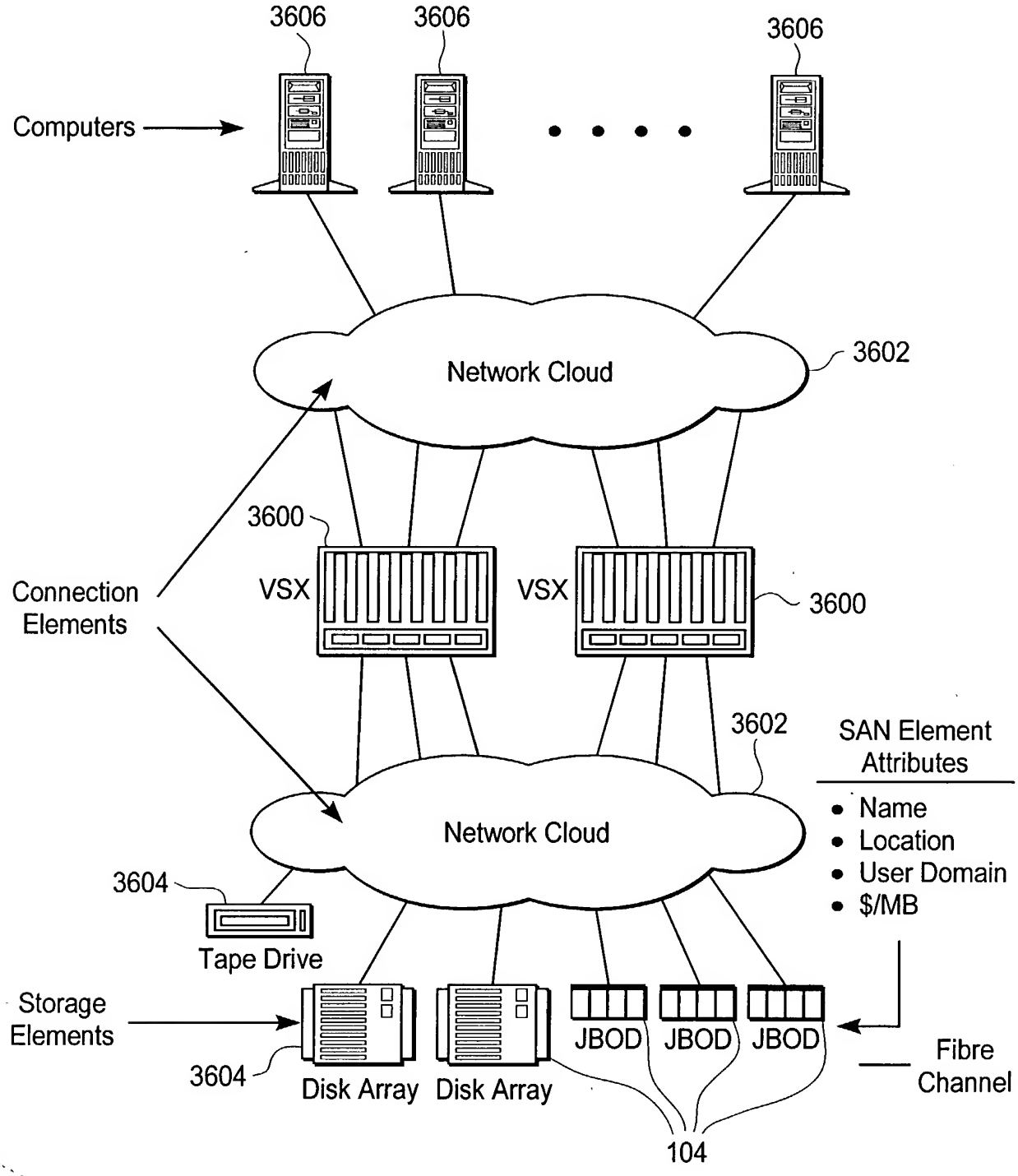

3606
3606
3606
Computers
Network Cloud
3602
3600
VSX
VSX
3600
Connection Elements
3602
Network Cloud
SAN Element Attributes
Name
Location
User Domain
$/MB
3604
Tape Drive
Storage Elements
JBOD
JBOD
JBOD
Fibre Channel
3604
Disk Array
Disk Array
104

FIG. 36

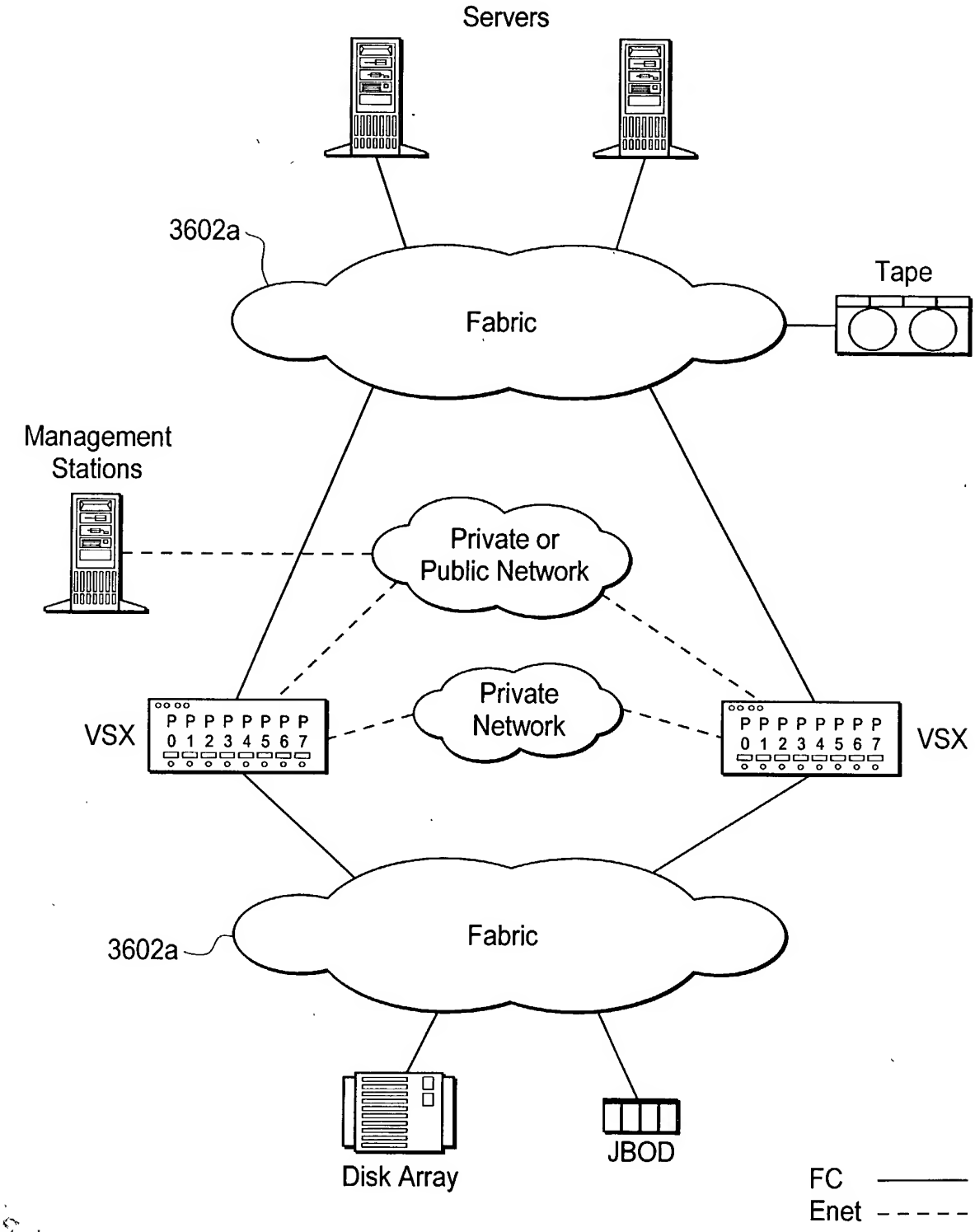


FIG. 36A Physical Setup for VSX-HA — Variation 1

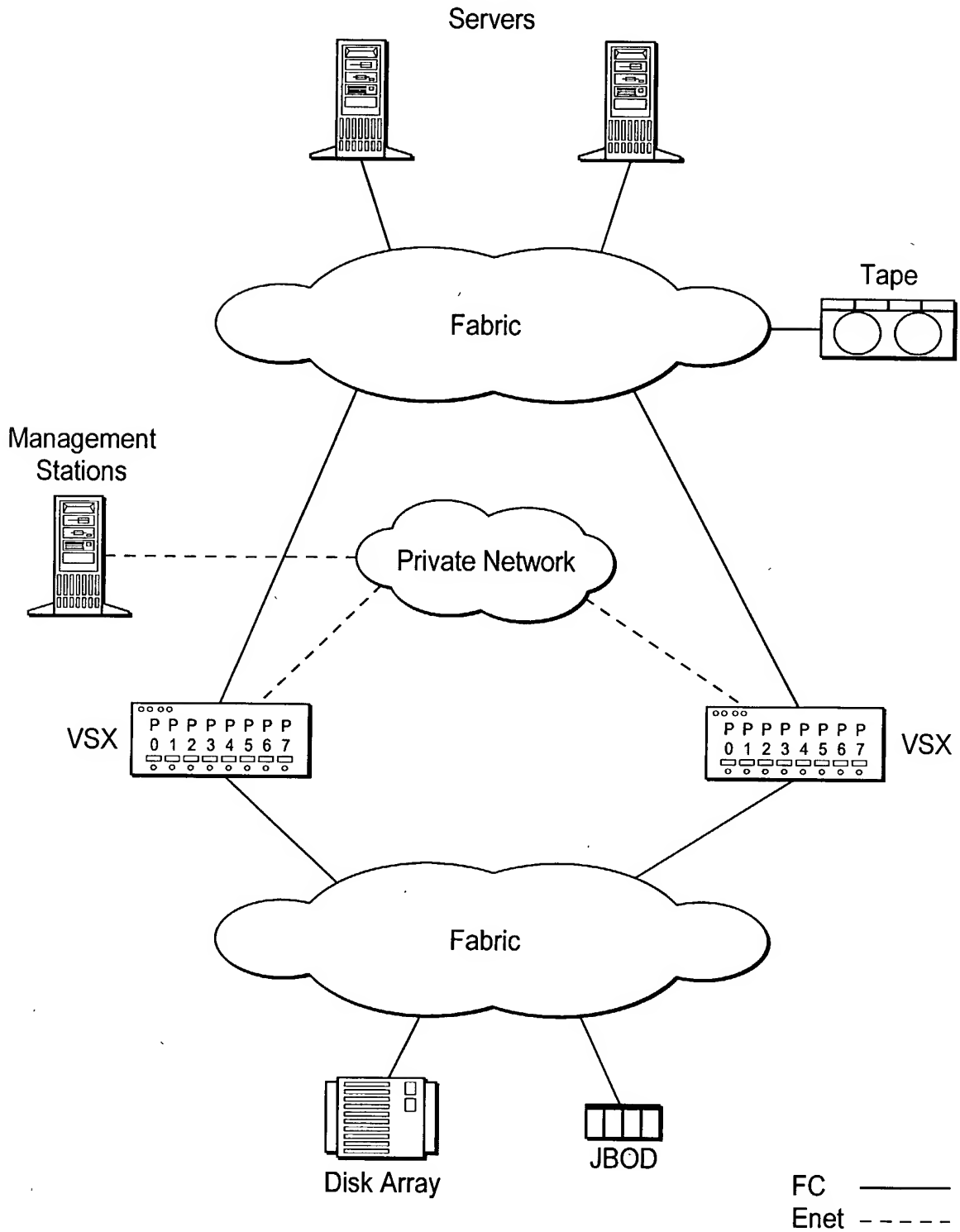


FIG. 36B Physical Setup for VSX-HA — Variation 2

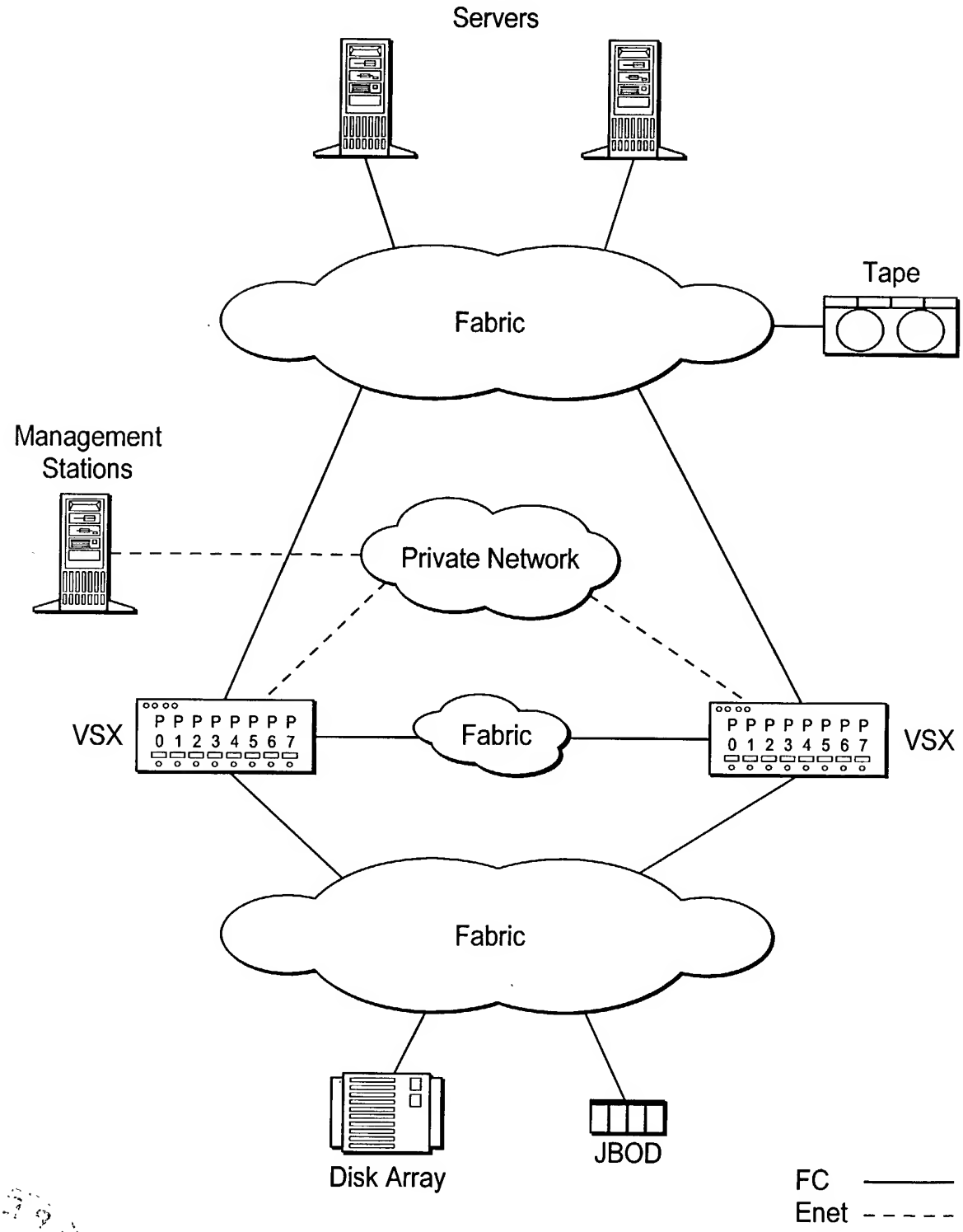


FIG. 36C Physical Setup for VSX-HA — Variation 3

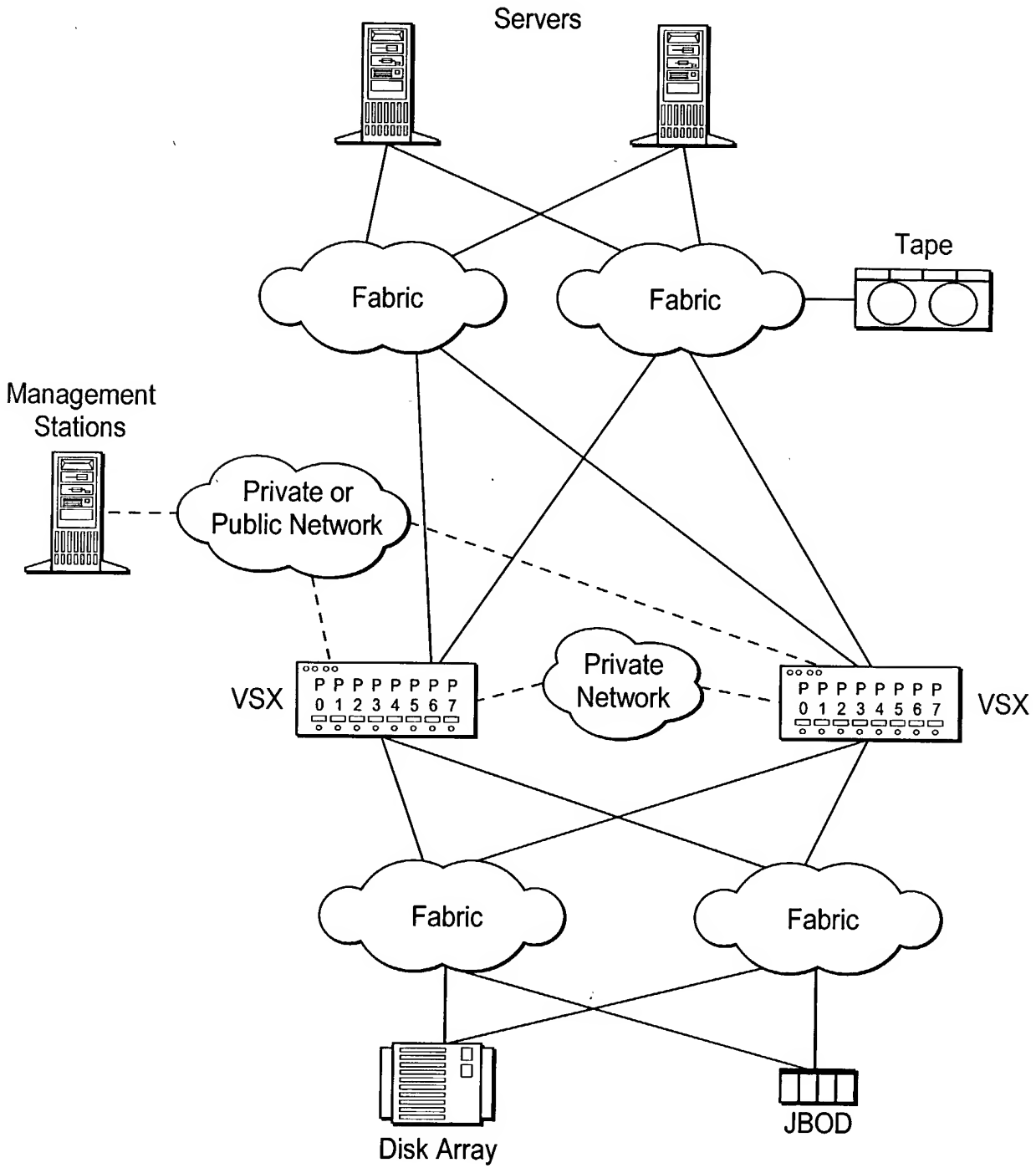


FIG. 36D Physical Setup for VSX-HA — Variation 4

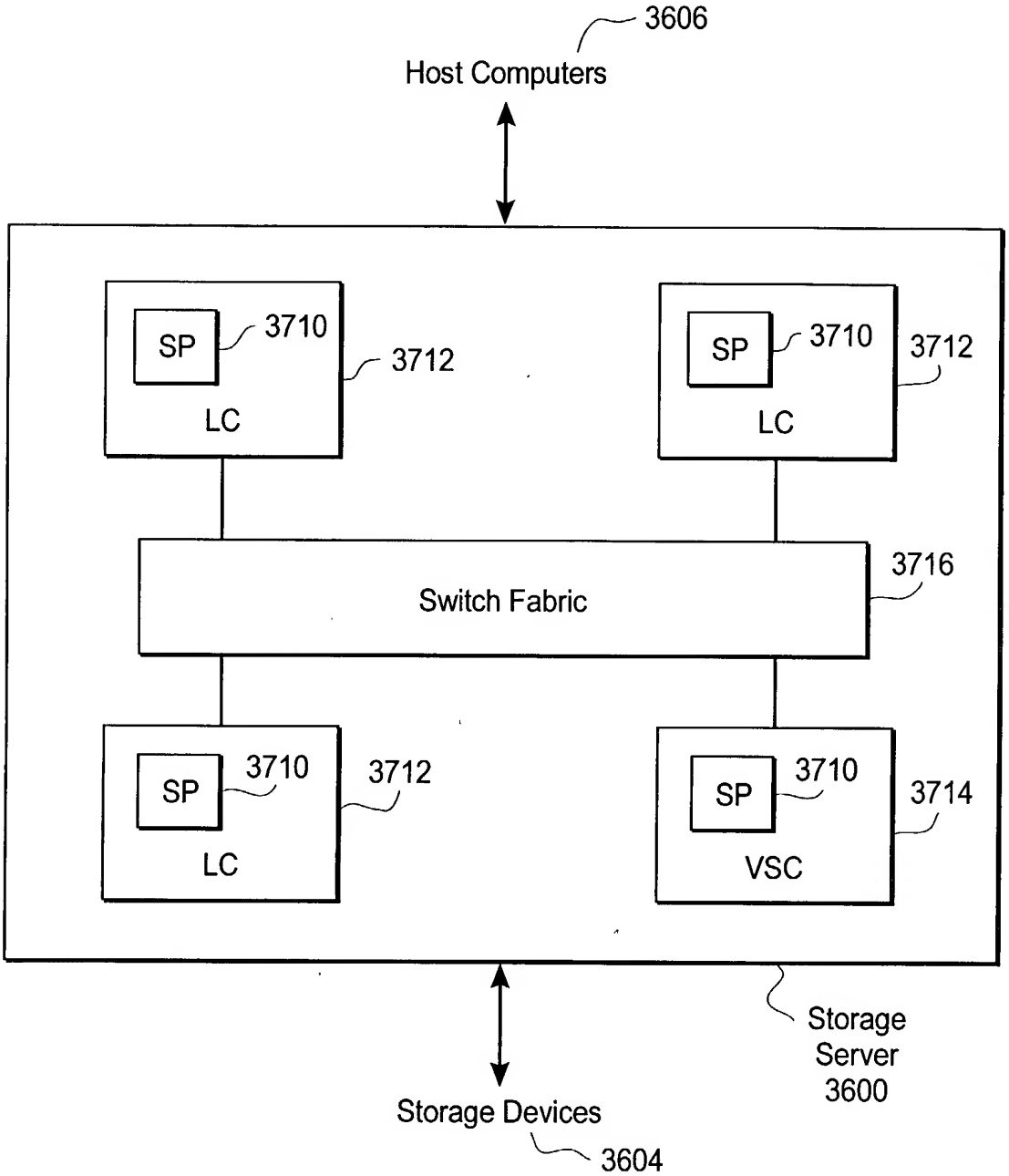


FIG. 37